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Shiraichi et al.

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(54) **FAN, MOLDING DIE, AND FLUID FEEDER**

USPC 416/235, 236 R, 236 A; 415/914
See application file for complete search history.

(75) Inventors: **Yukishige Shiraichi**, Osaka (JP);
Masaki Ohtsuka, Osaka (JP); **Masaya**
Takahashi, Osaka (JP)

(73) Assignee: **SHARP KABUSHIKI KAISHA**, Osaka
(JP)

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F04D 29/28 (2006.01)

(52) **U.S. Cl.**

CPC **F04D 19/002** (2013.01); **F04D 29/283**
(2013.01); **F04D 29/30** (2013.01)

(58) **Field of Classification Search**

CPC F04D 29/30; F04D 29/281; F04D 29/283;
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F04D 29/68; F04D 29/681; F01D 5/141;
F01D 5/145; F05D 2240/31; F05D 2240/305;
F05D 2240/306; F05D 2240/301; F05D
2300/44

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Primary Examiner — Dwayne J White

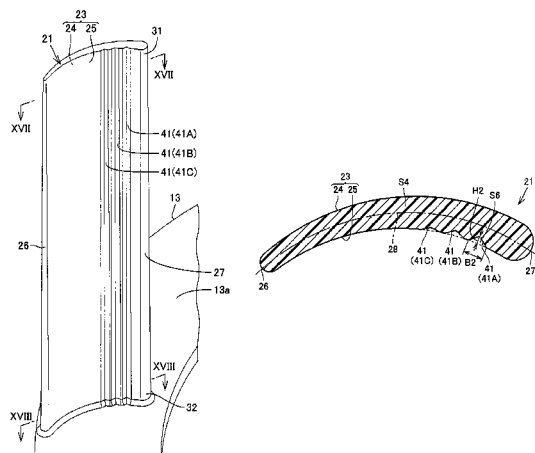
Assistant Examiner — Joshua R Beebe

(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A cross-flow fan includes a plurality of fan blades. The fan blade has an inner edge portion arranged on an inner circumferential side and an outer edge portion arranged on an outer circumferential side. In the fan blade, a blade surface extending between the inner edge portion and the outer edge portion and constituted of a positive pressure surface and a negative pressure surface is formed. The fan blade has such a blade cross-sectional shape that a large-thickness portion at which a thickness between the positive pressure surface and the negative pressure surface is greatest is arranged closer to the inner edge portion. A recess recessed in the blade surface is formed at a position closer to the inner edge portion where the large-thickness portion is arranged, than to the outer edge portion.

12 Claims, 30 Drawing Sheets



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FIG. 1

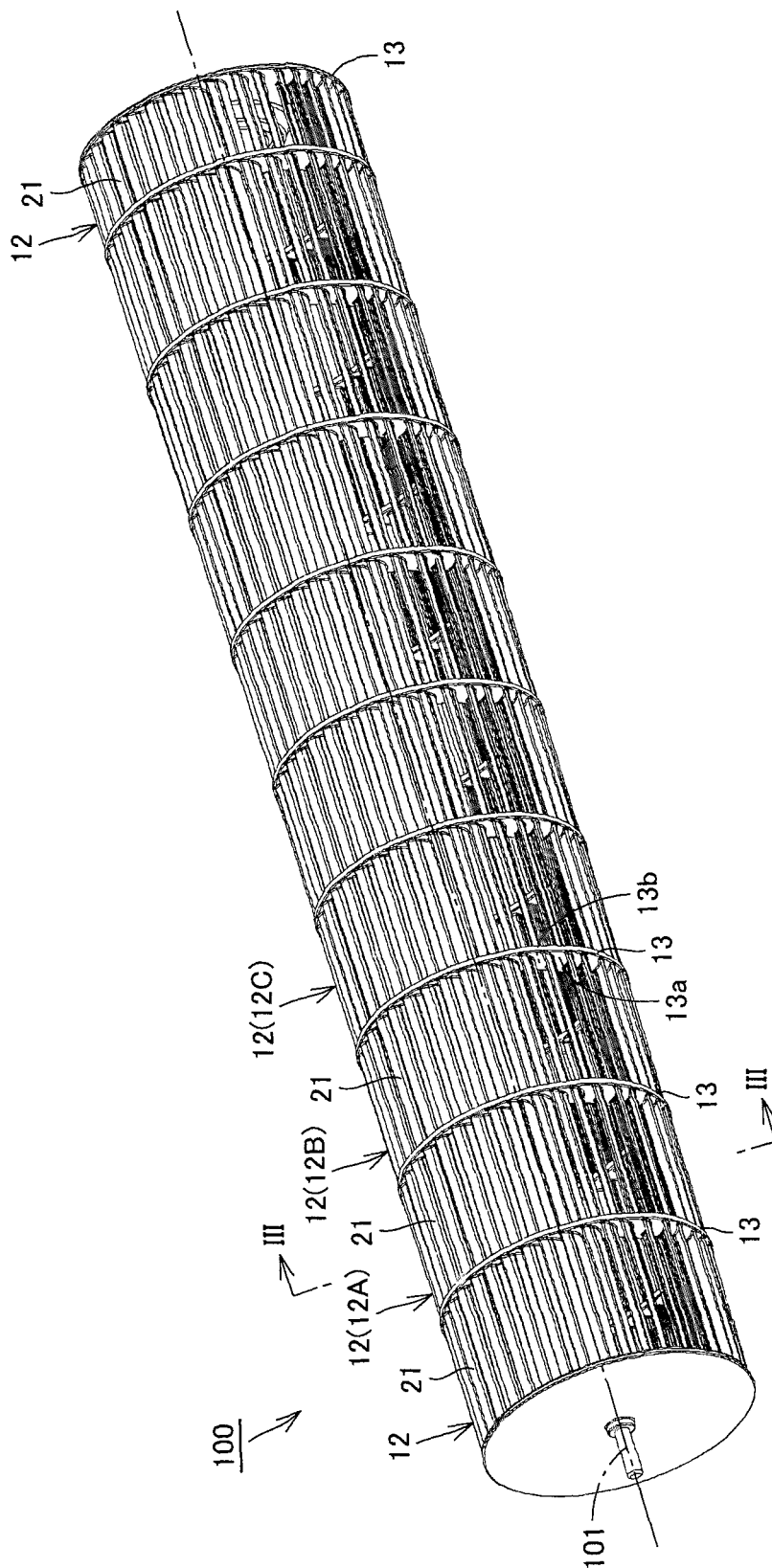


FIG. 2

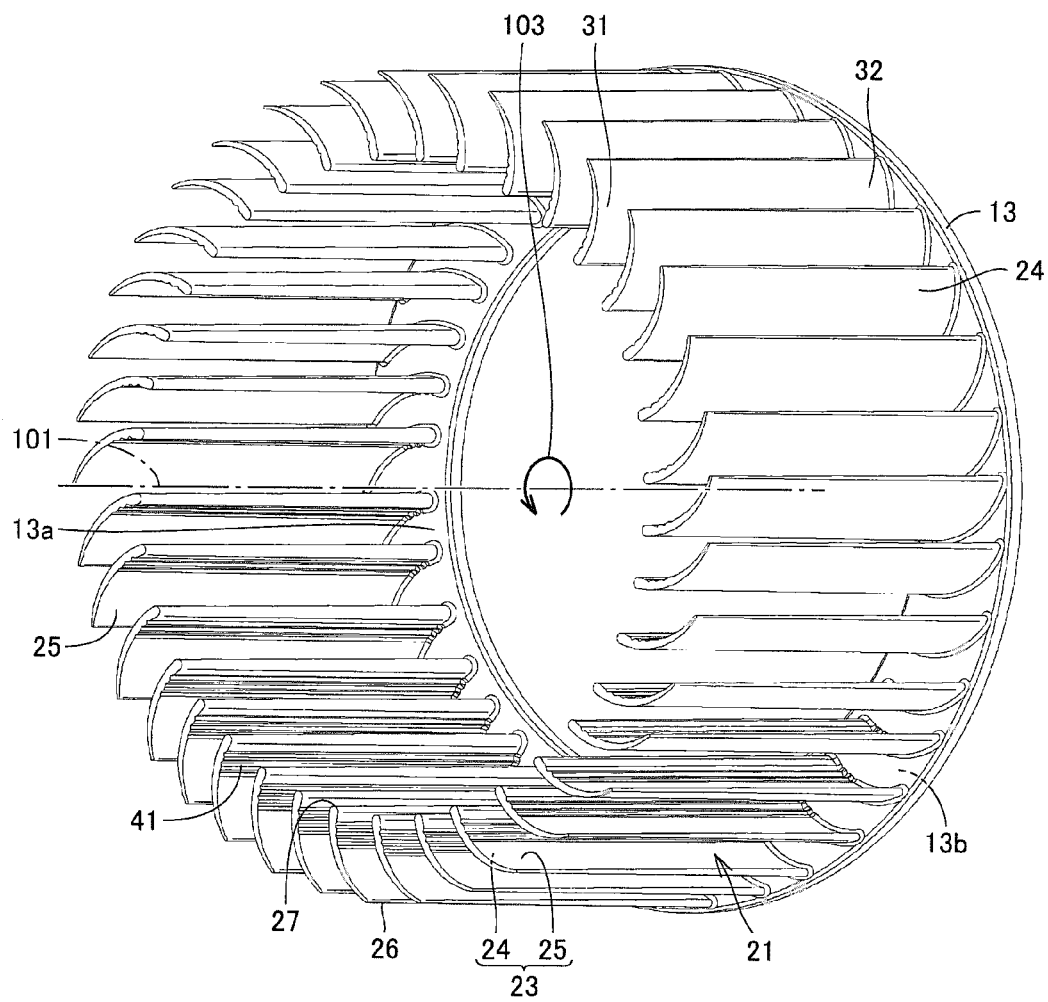


FIG.3

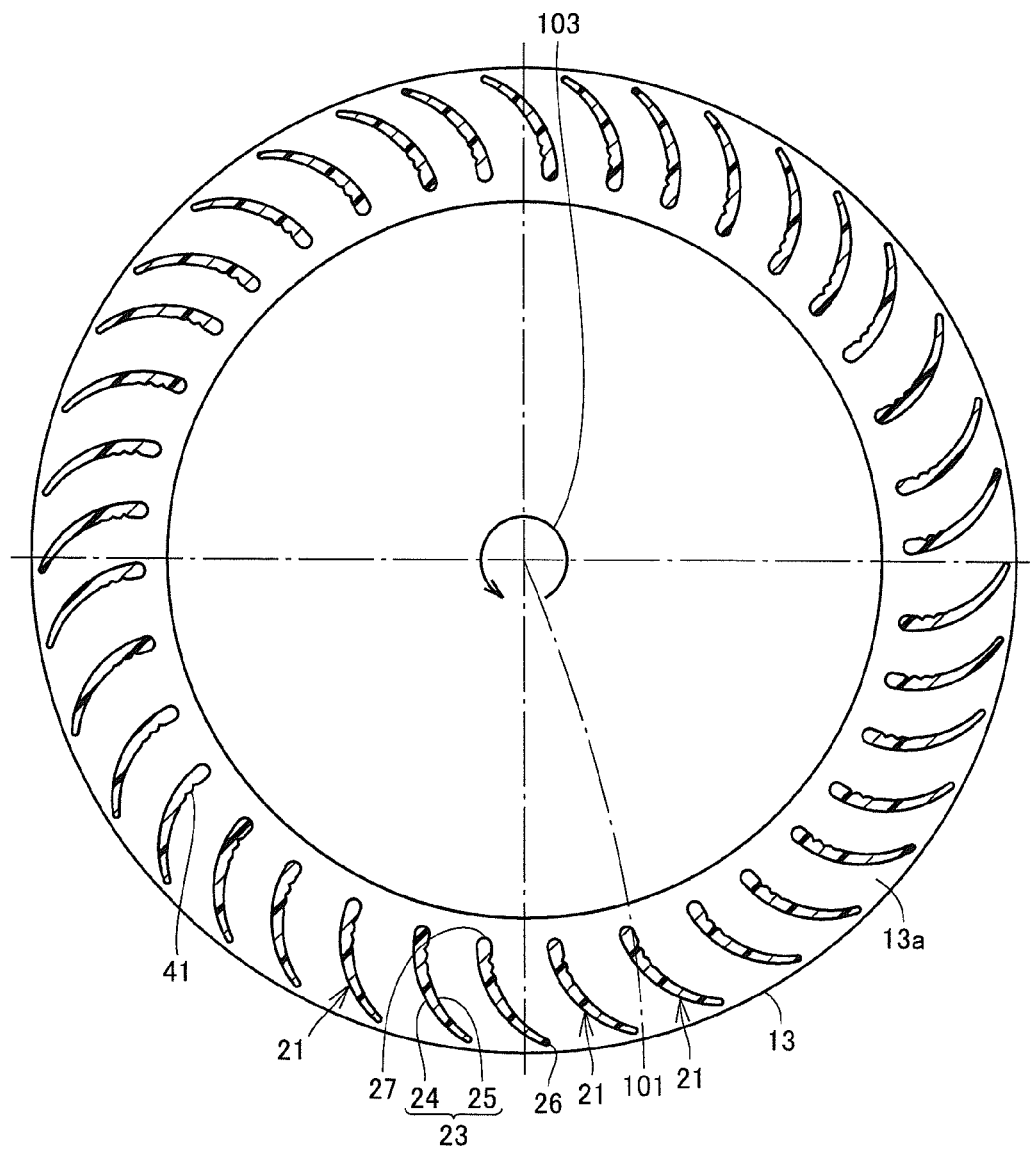


FIG.4

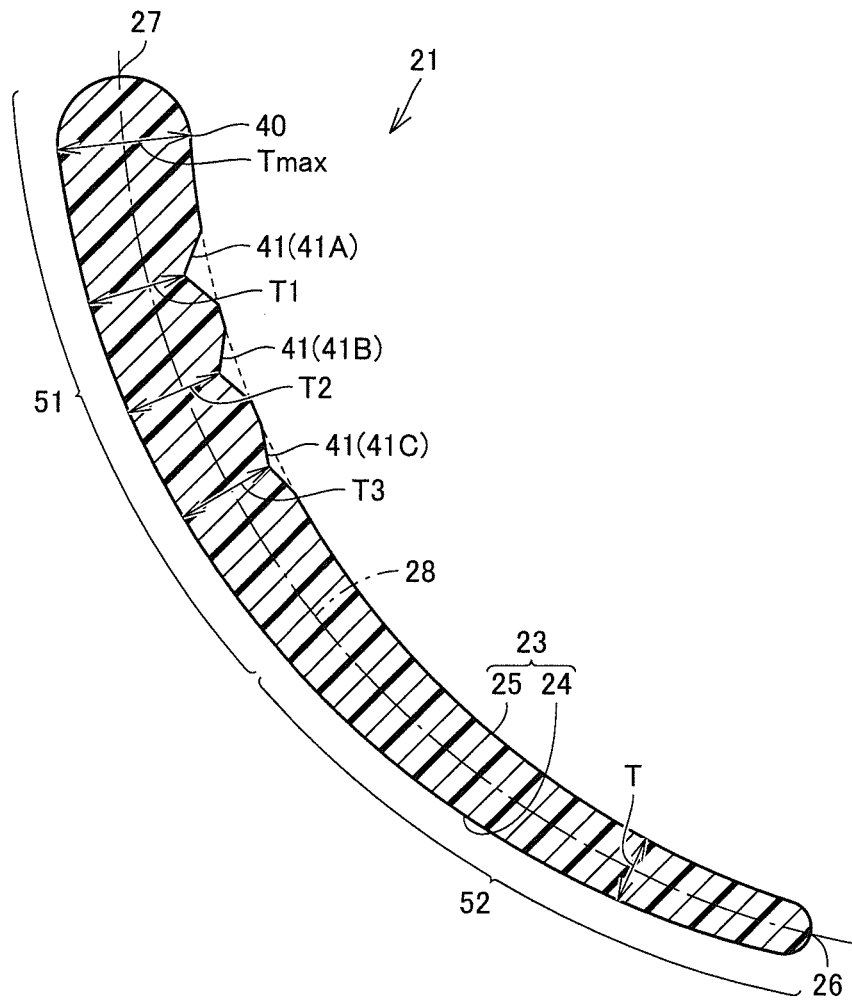


FIG. 5

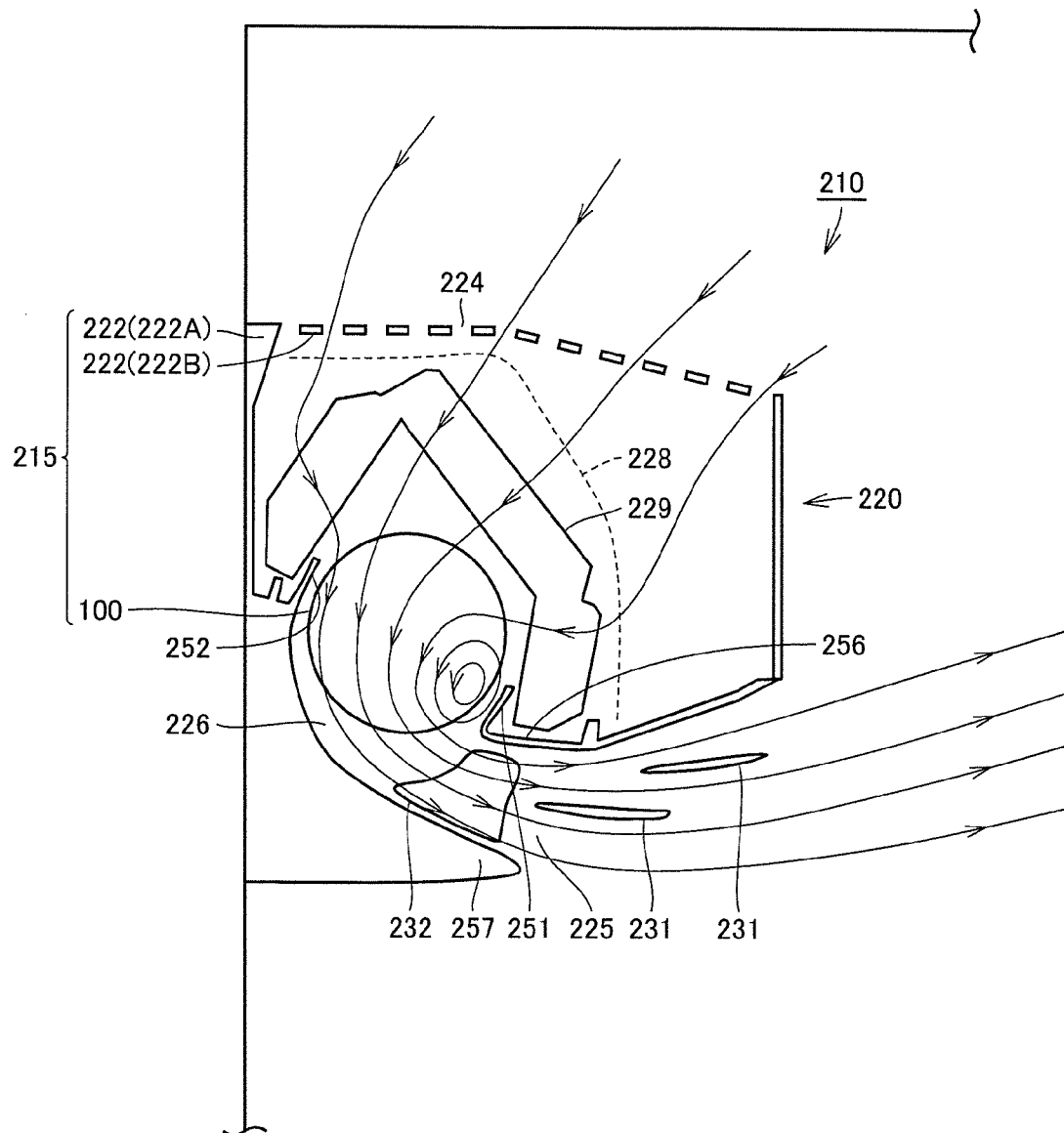


FIG. 6

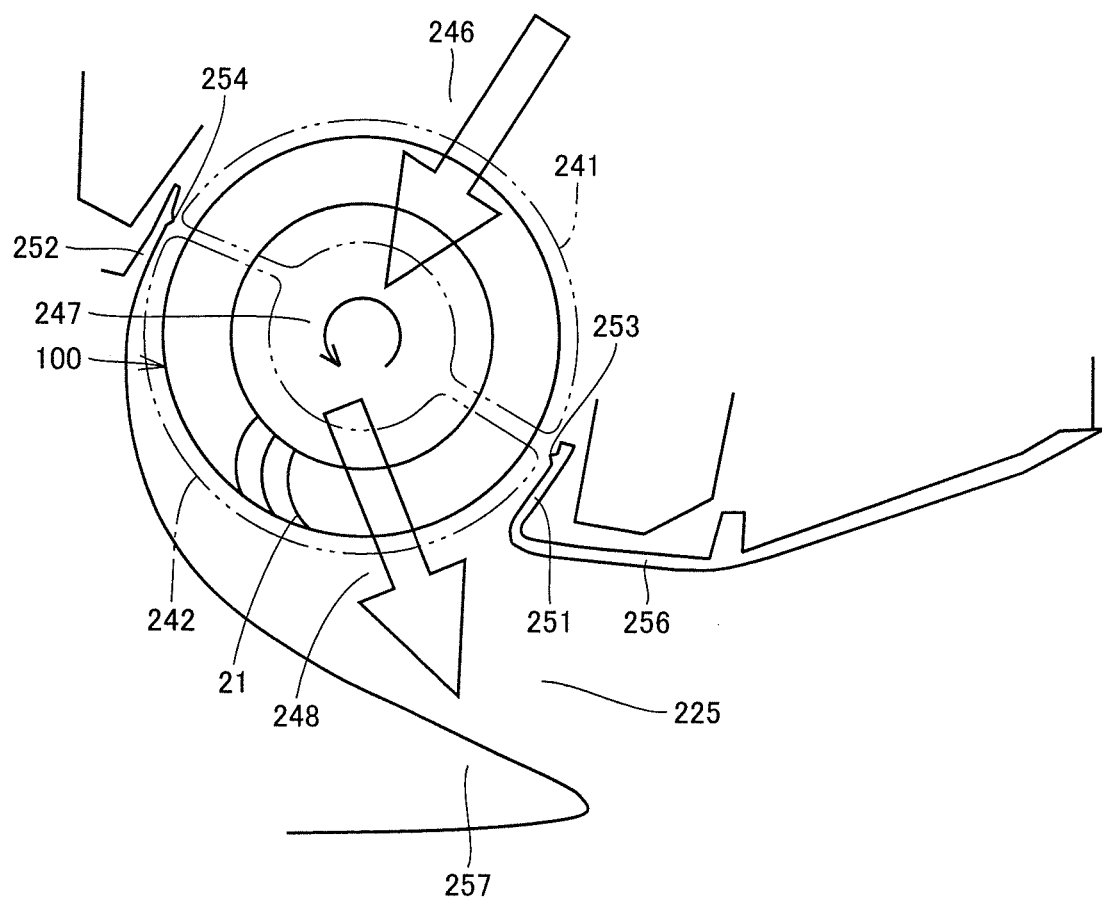


FIG. 7

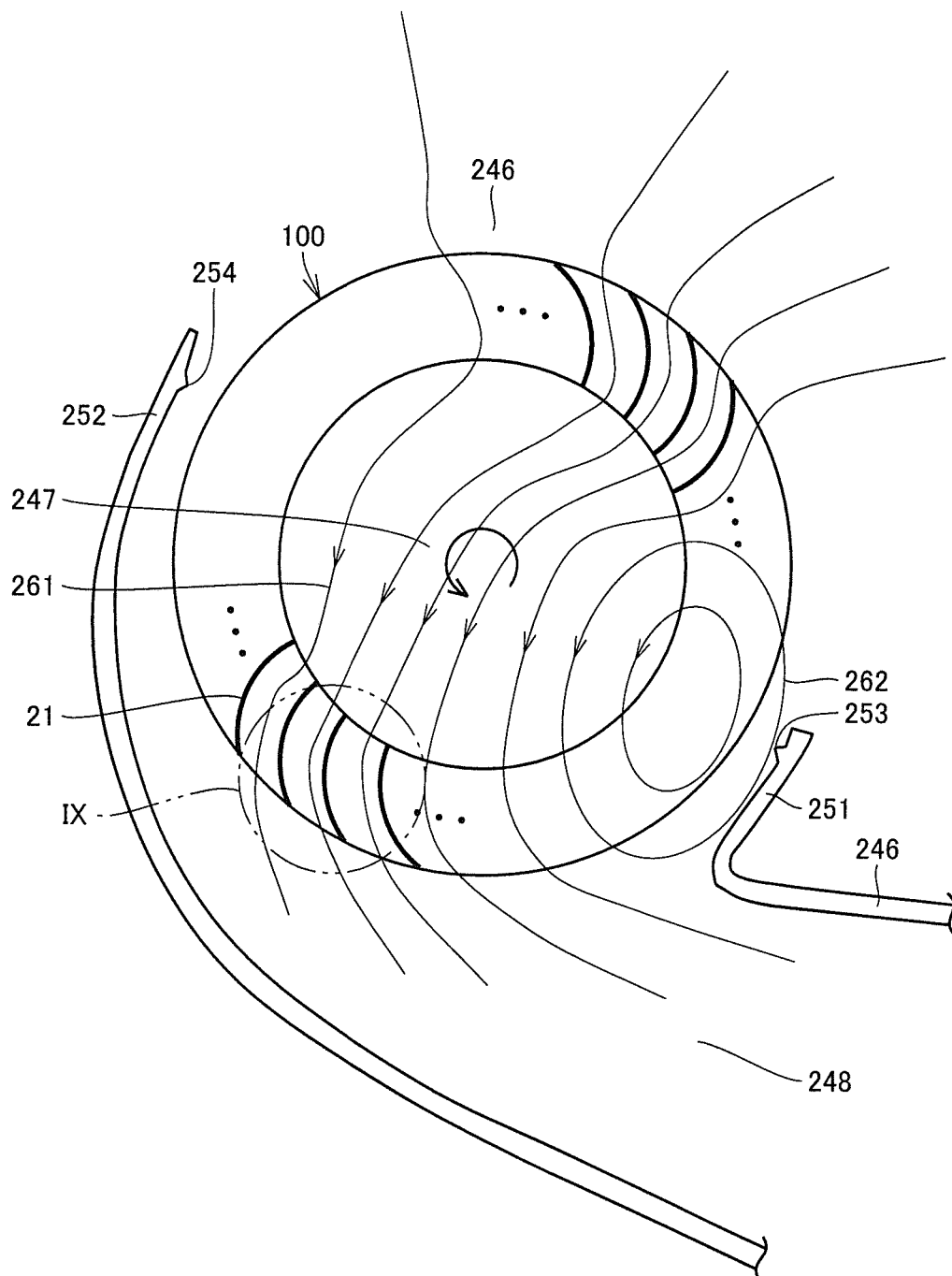


FIG. 8

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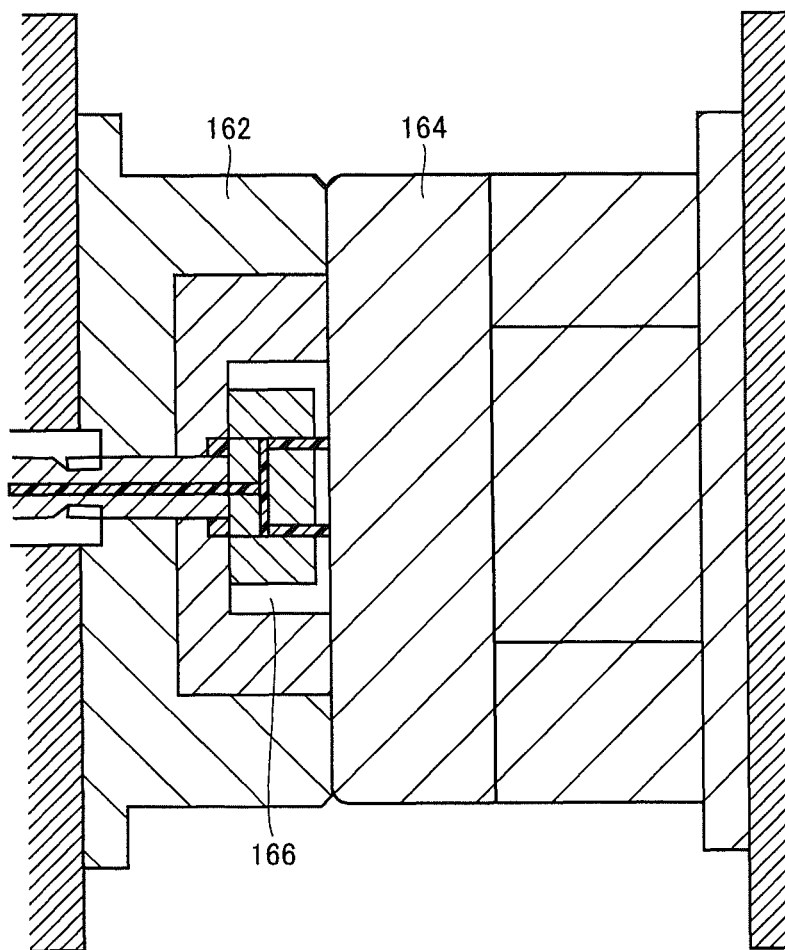


FIG. 9

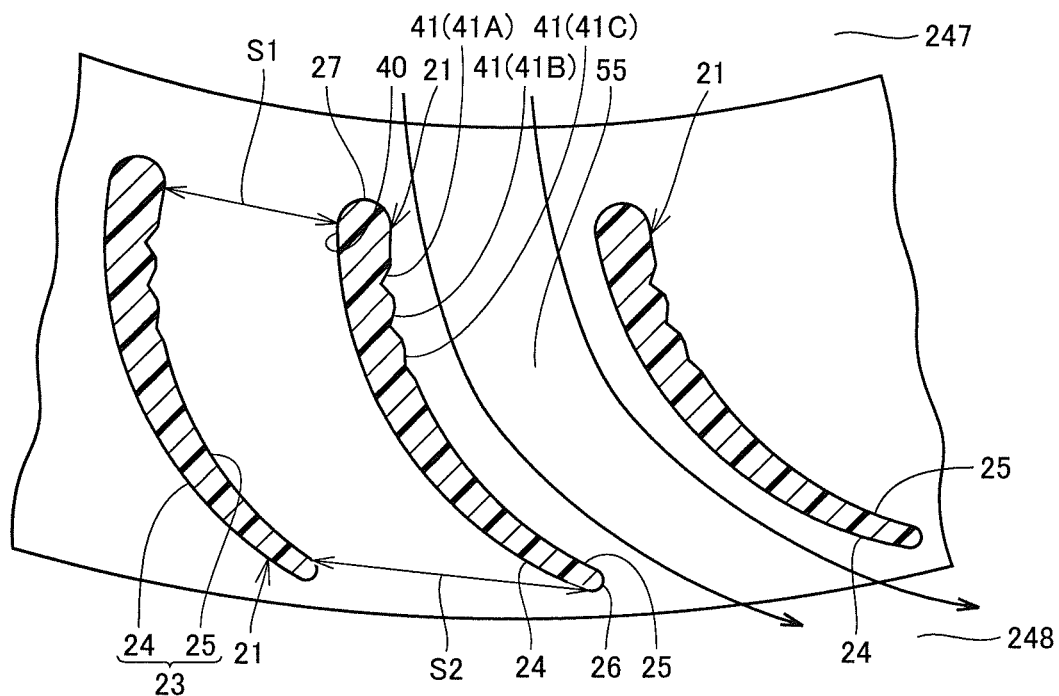


FIG. 10

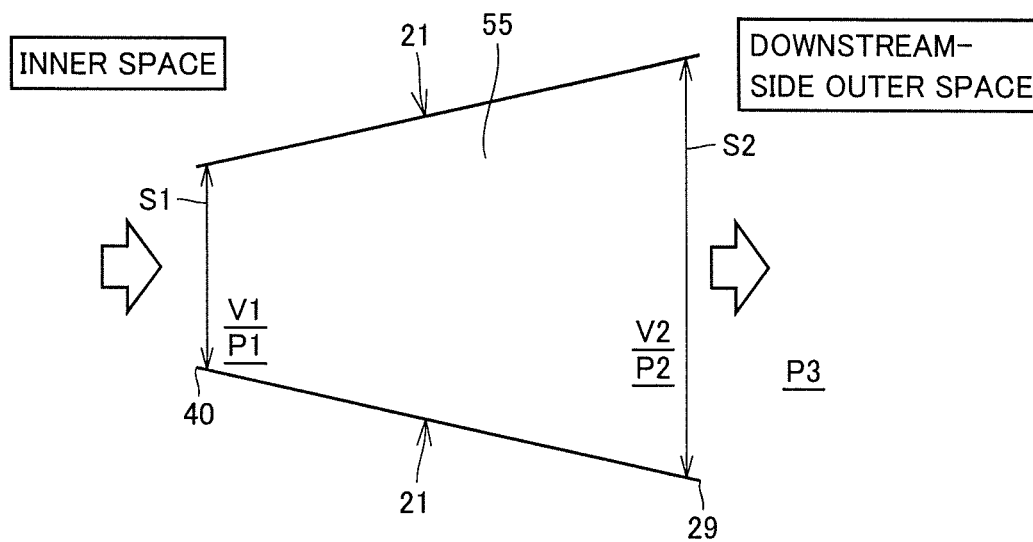


FIG.11

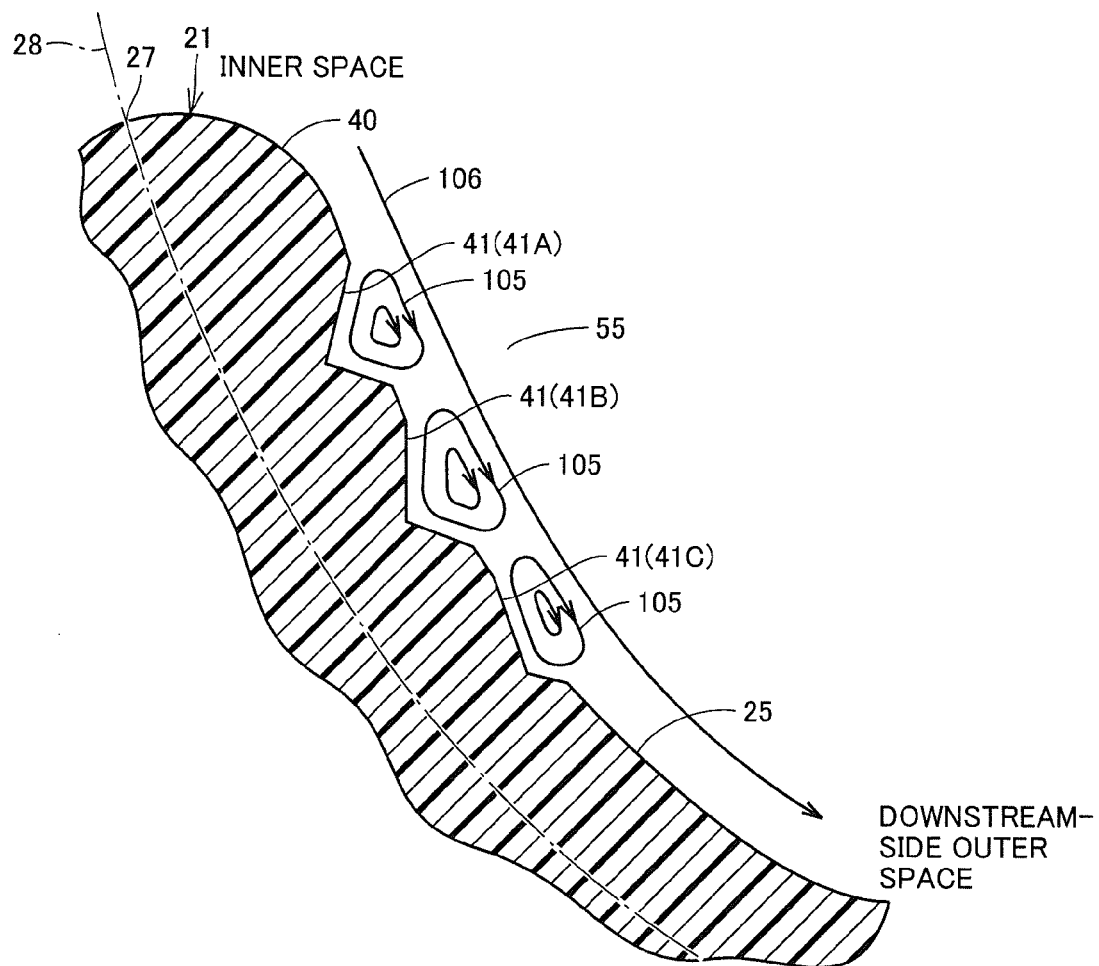
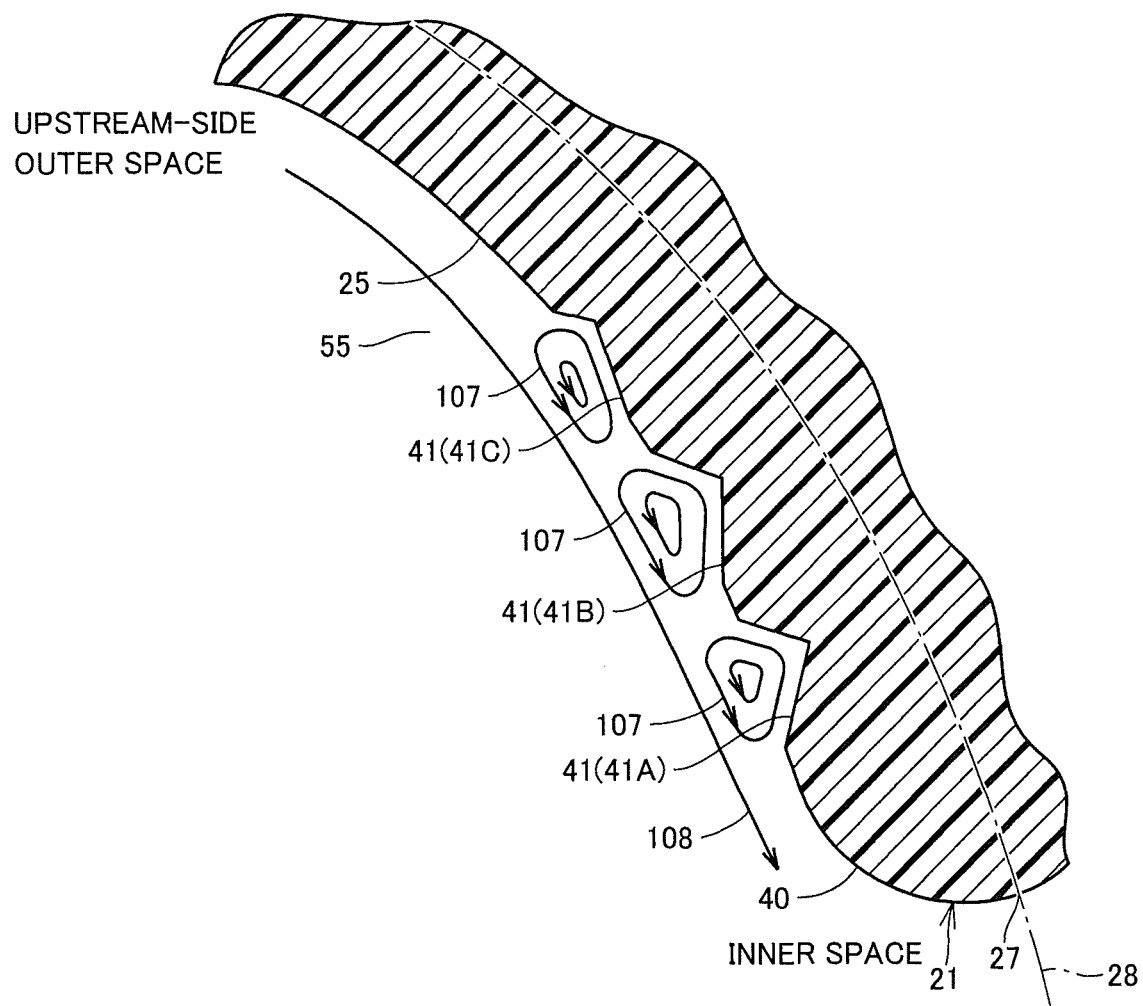


FIG.12



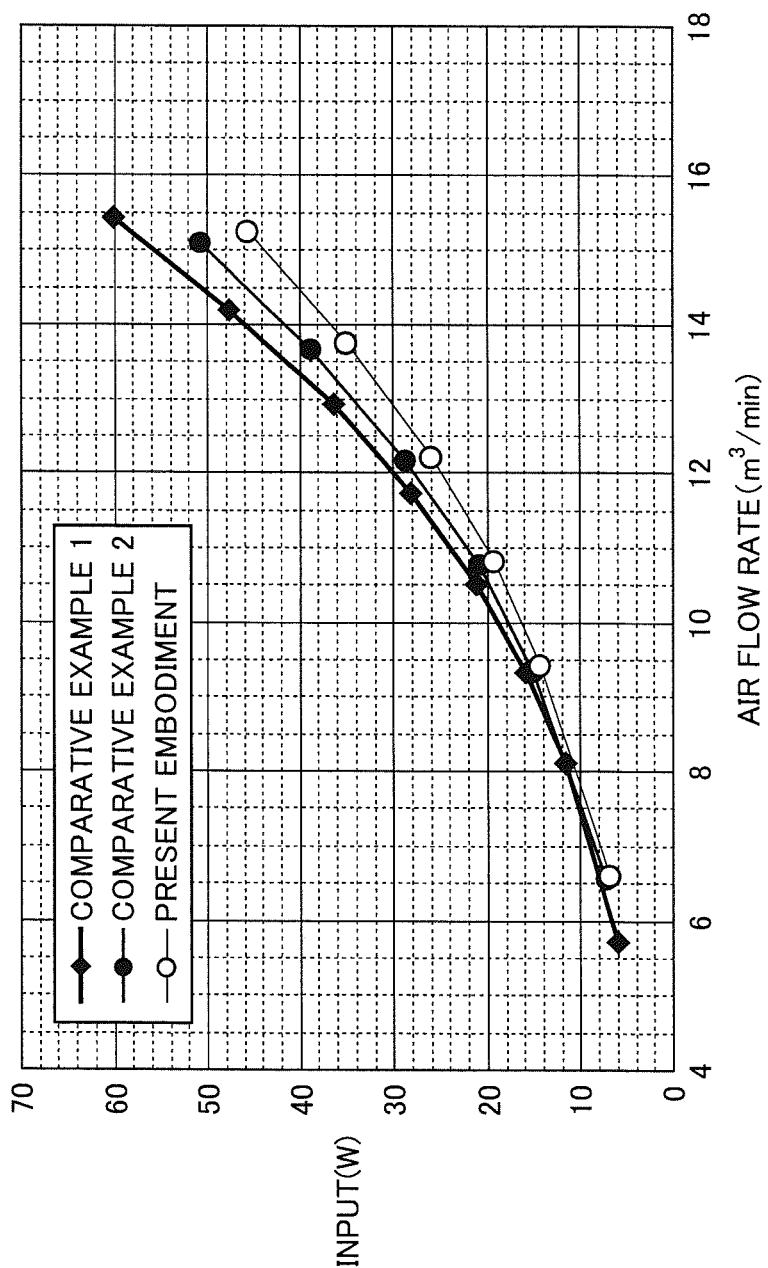


FIG.13

FIG.14

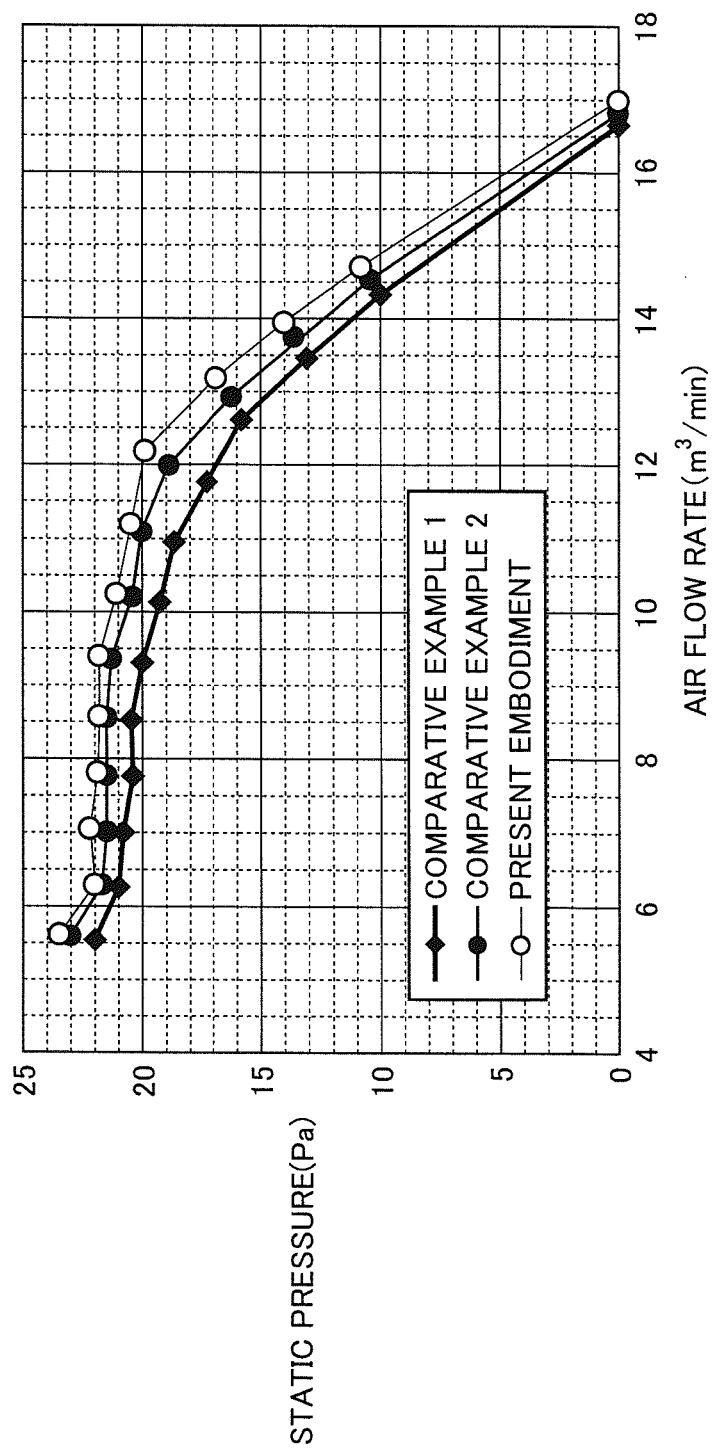


FIG.15

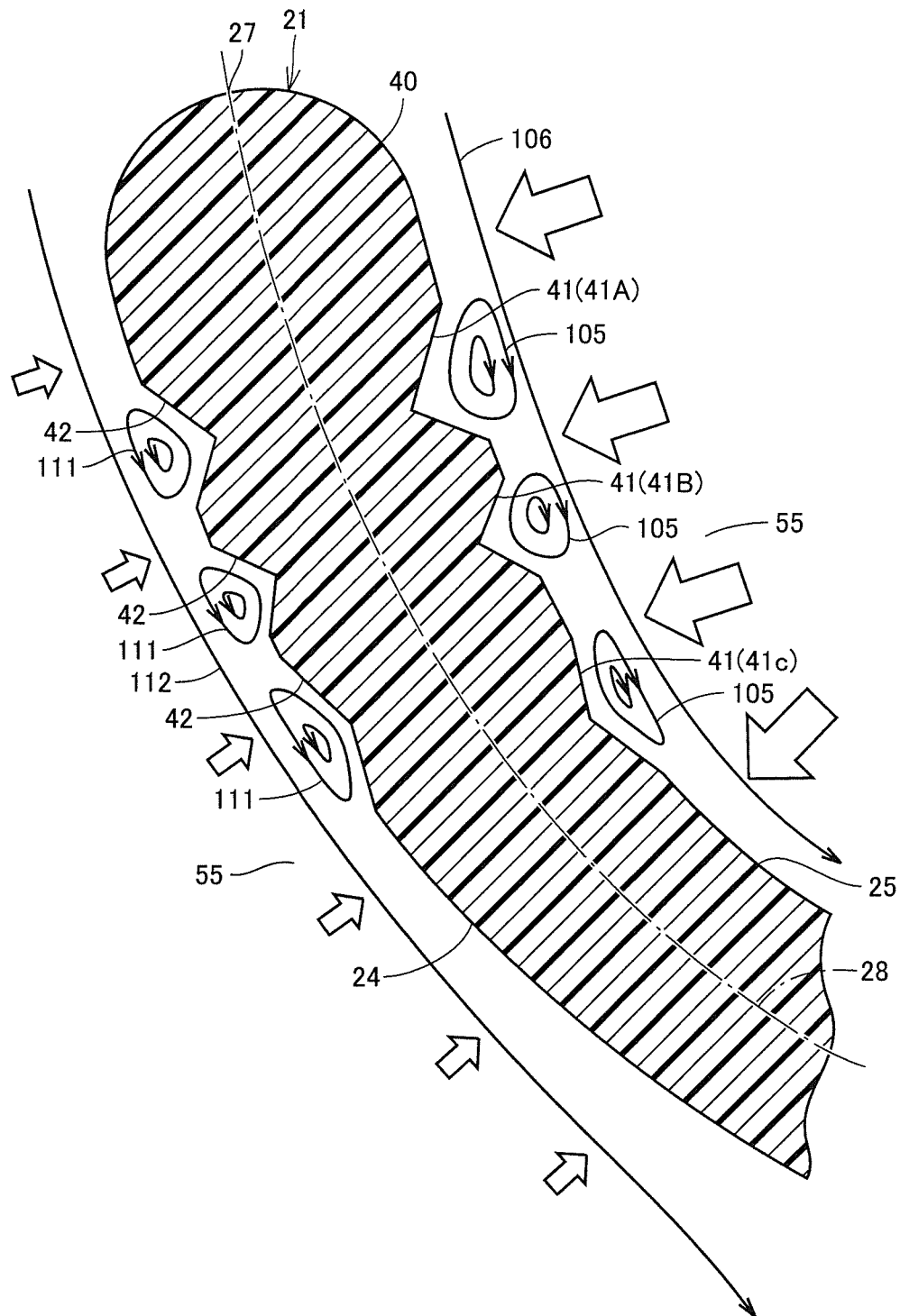


FIG.16

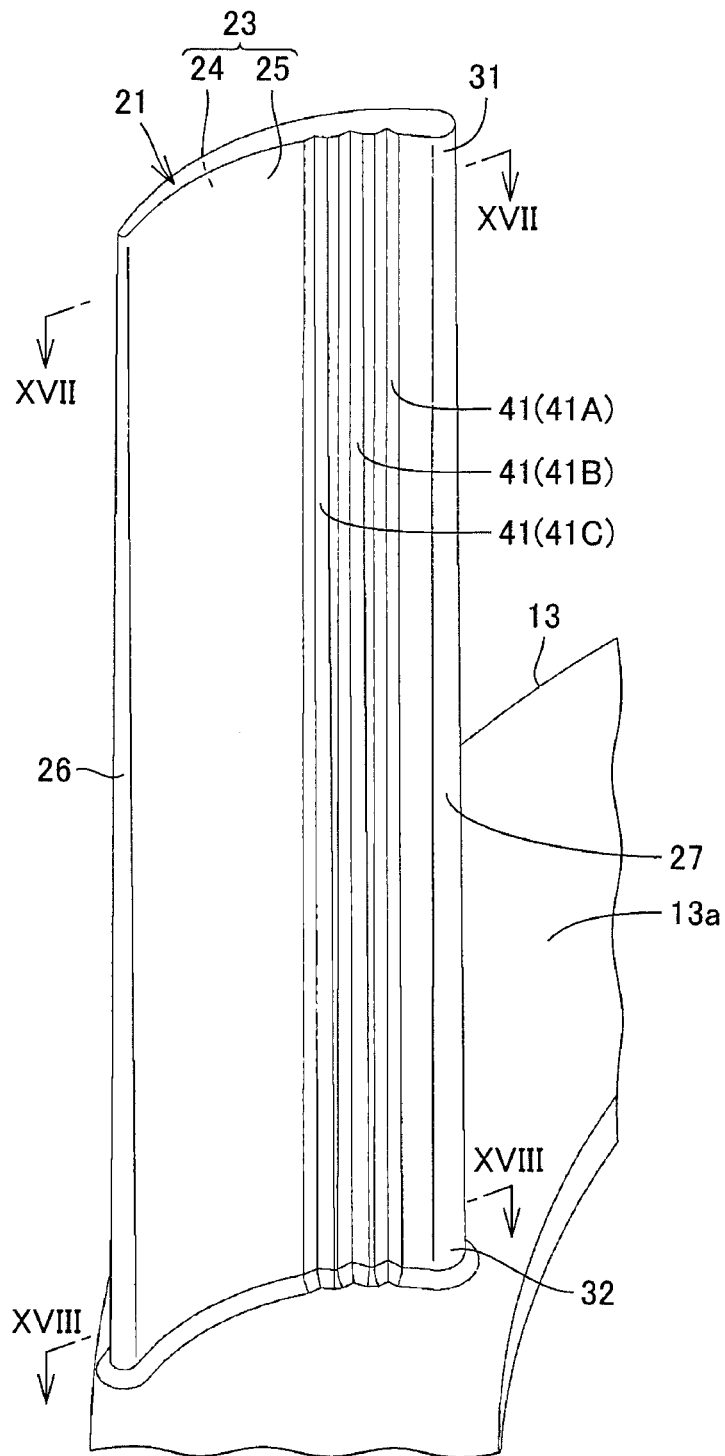


FIG.17

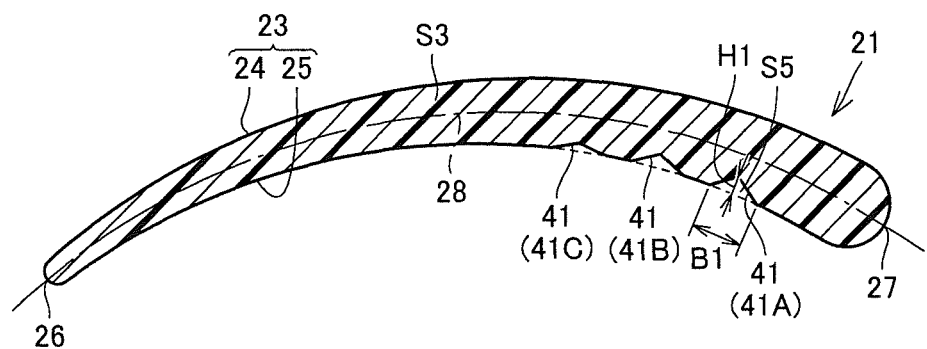


FIG.18

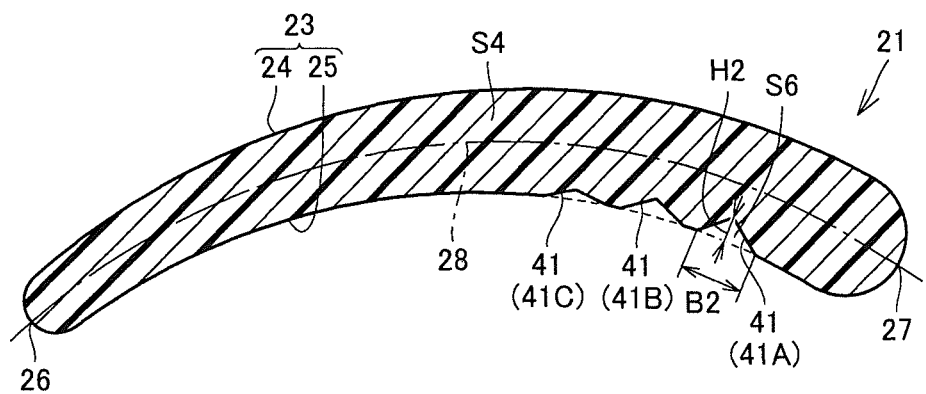


FIG.19

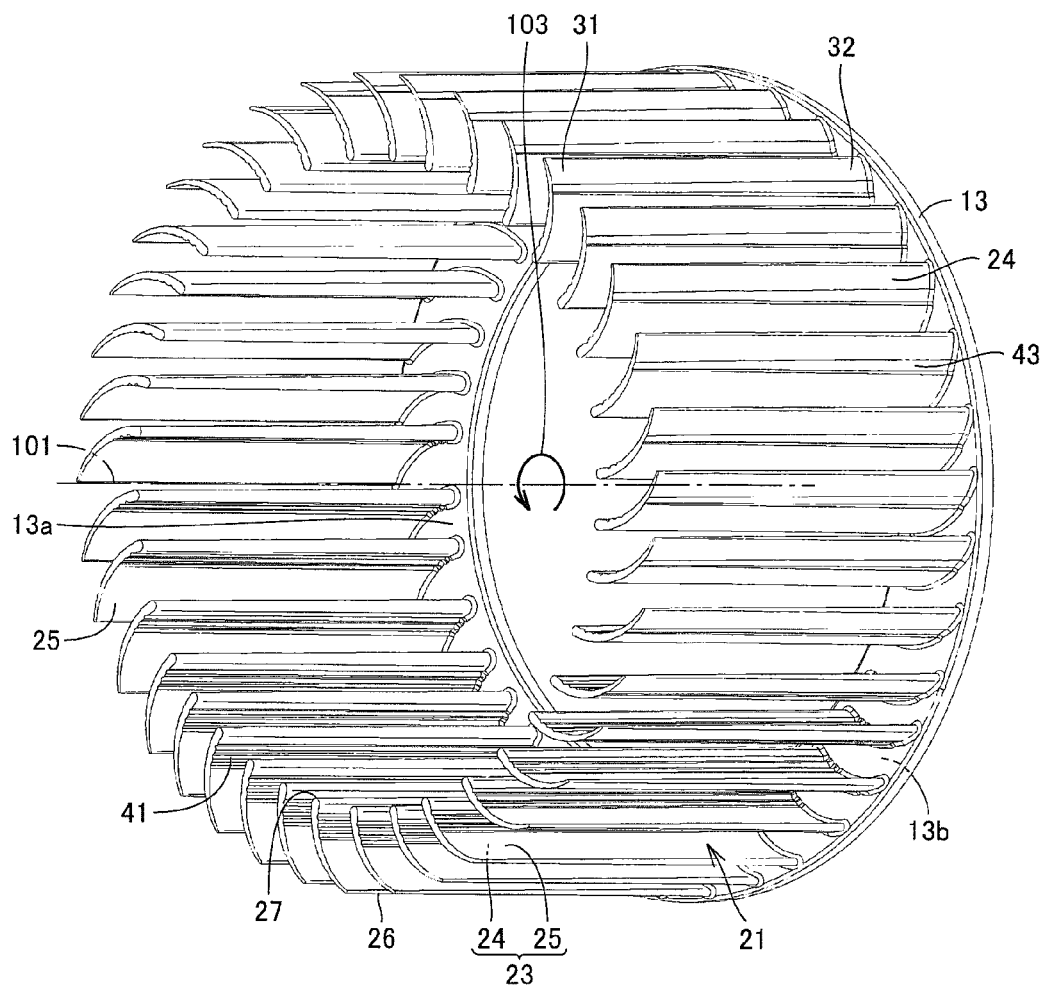


FIG.20

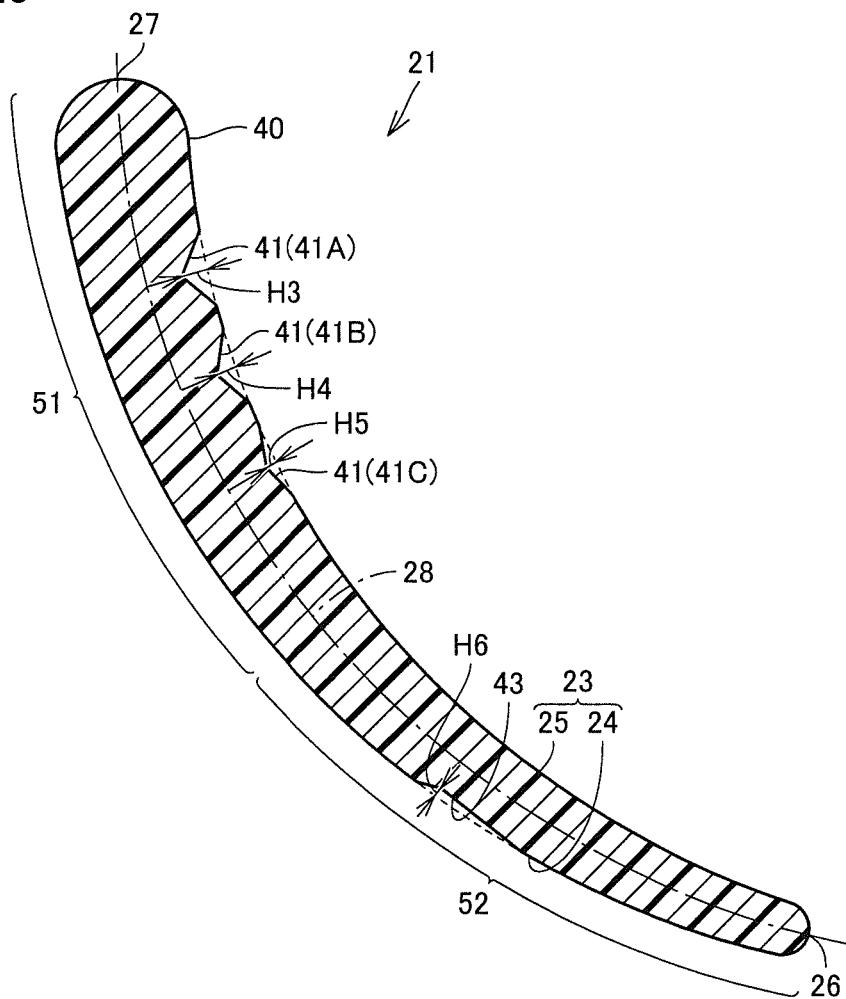


FIG.21

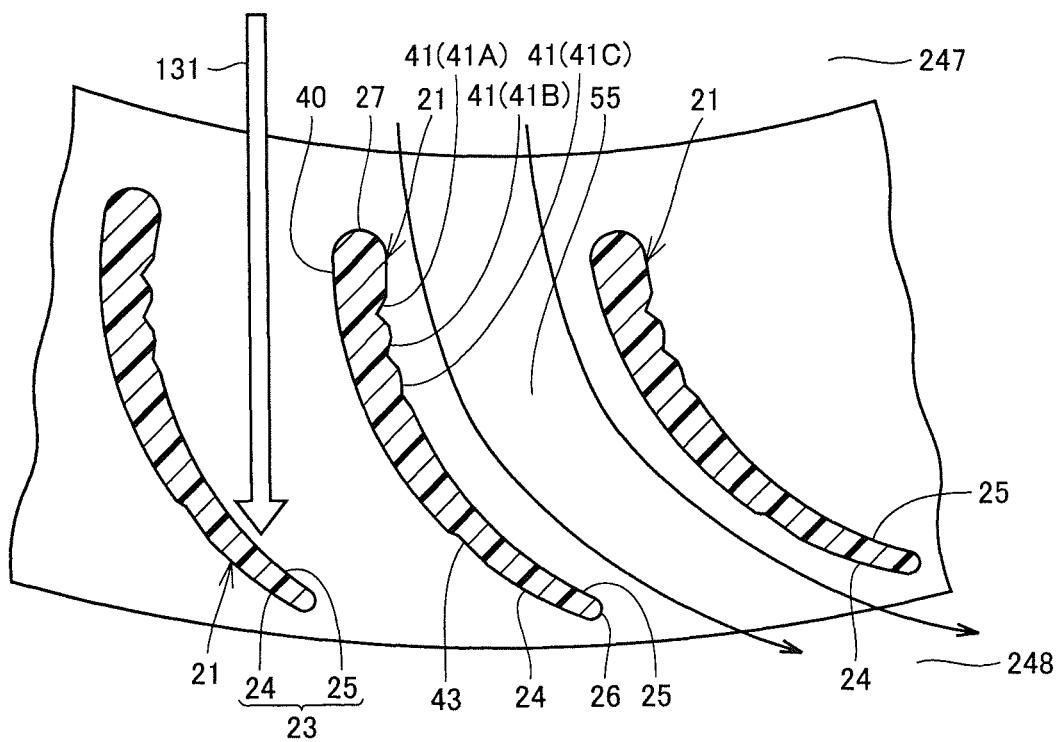


FIG.22

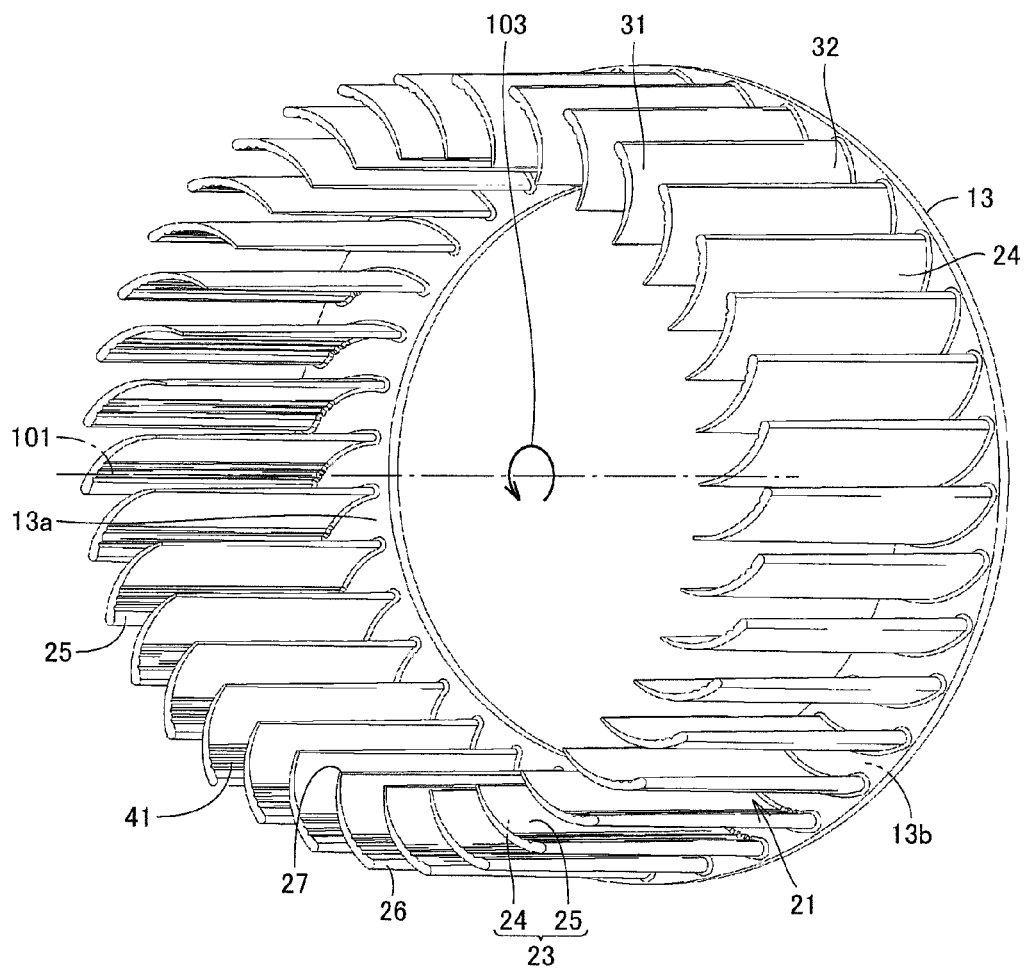


FIG.23

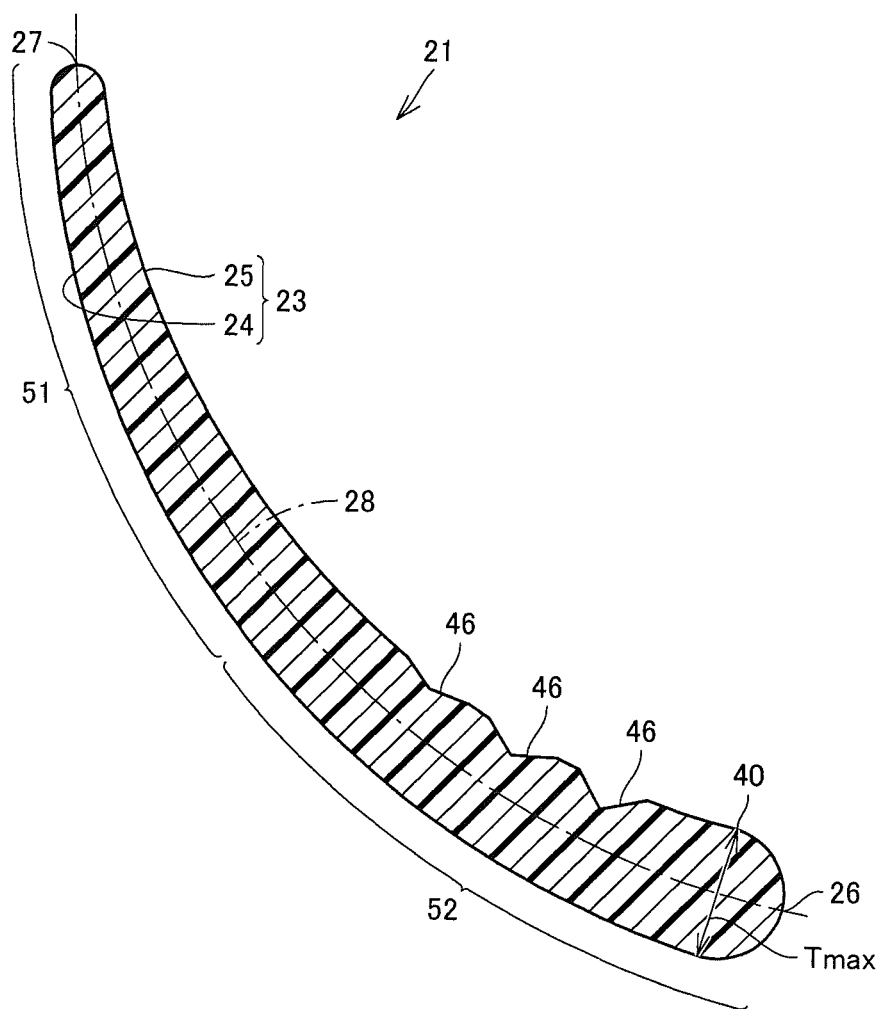


FIG. 24

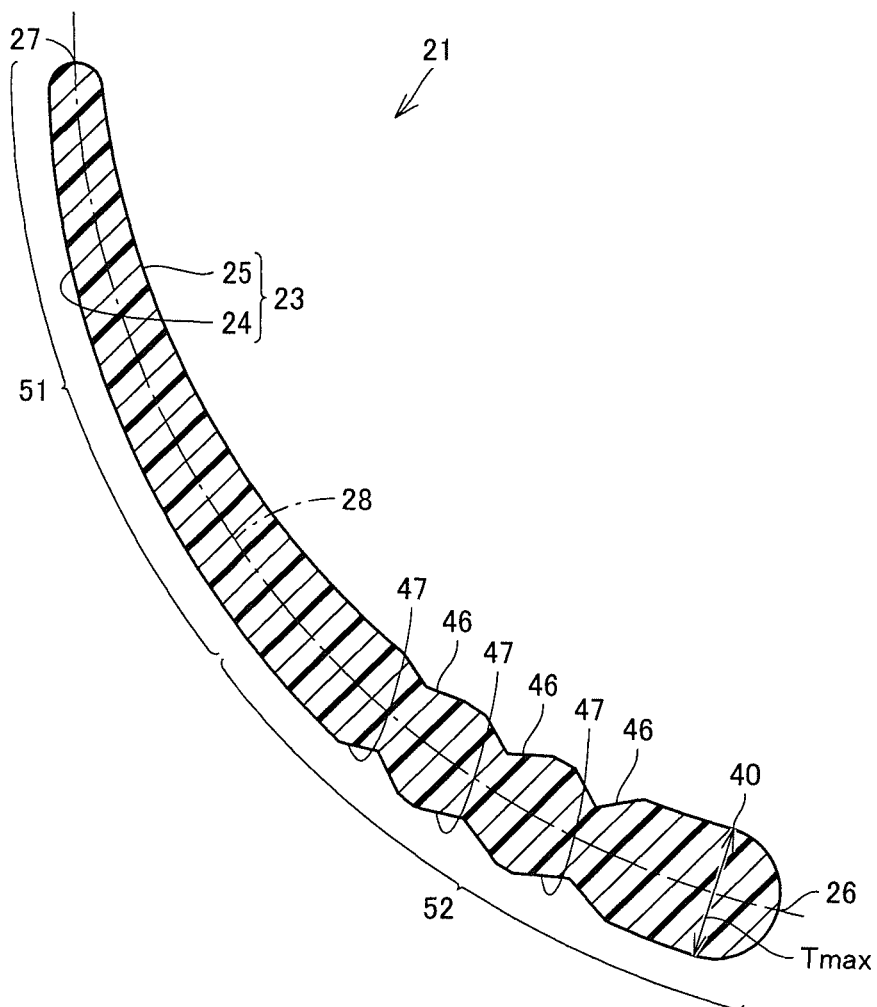


FIG.25

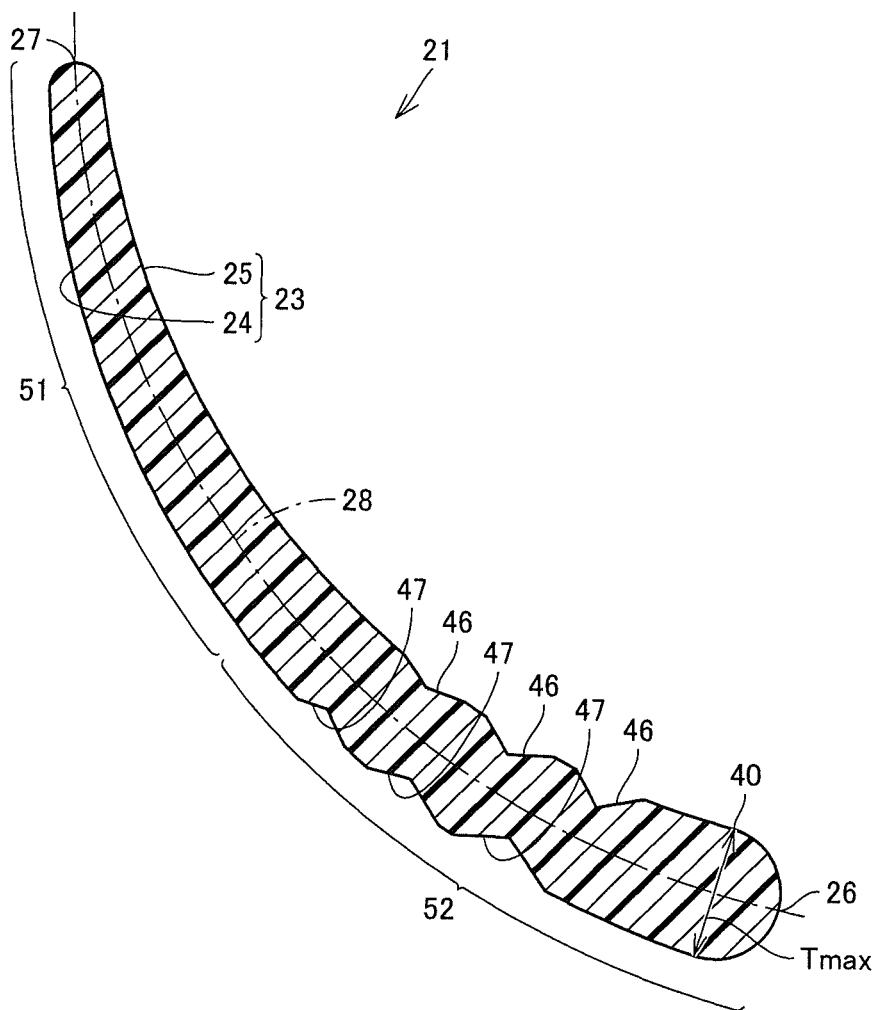


FIG.26

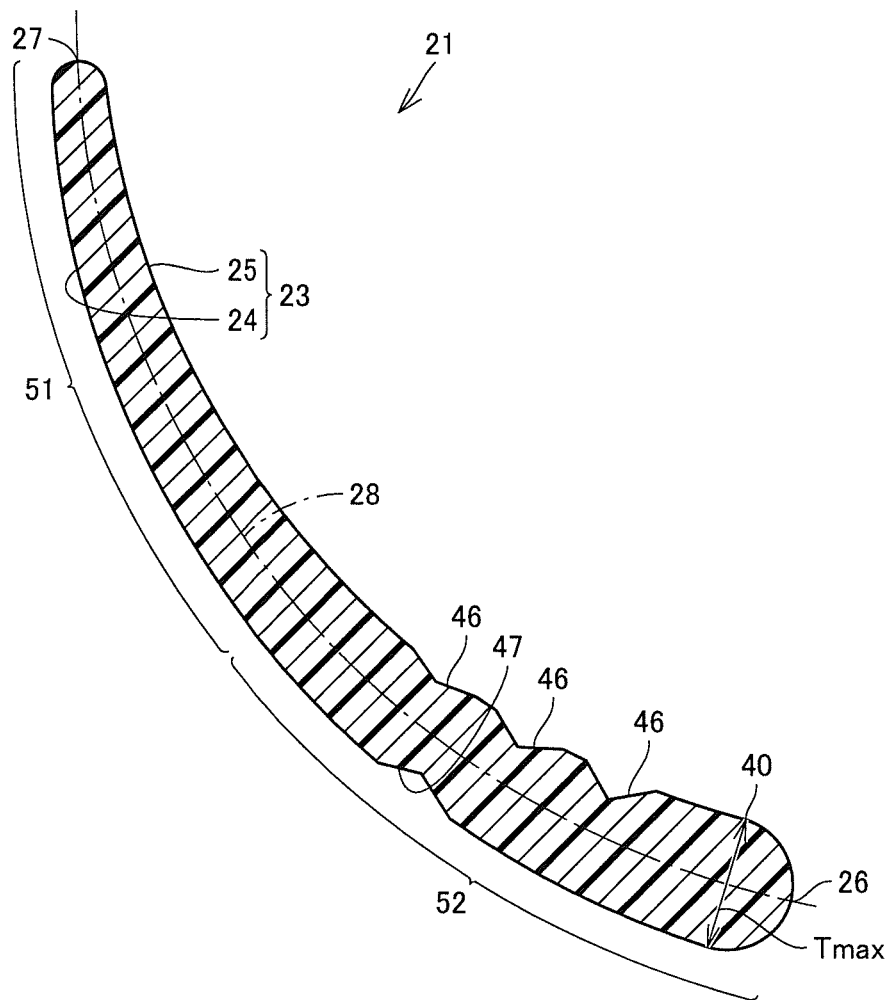


FIG.27

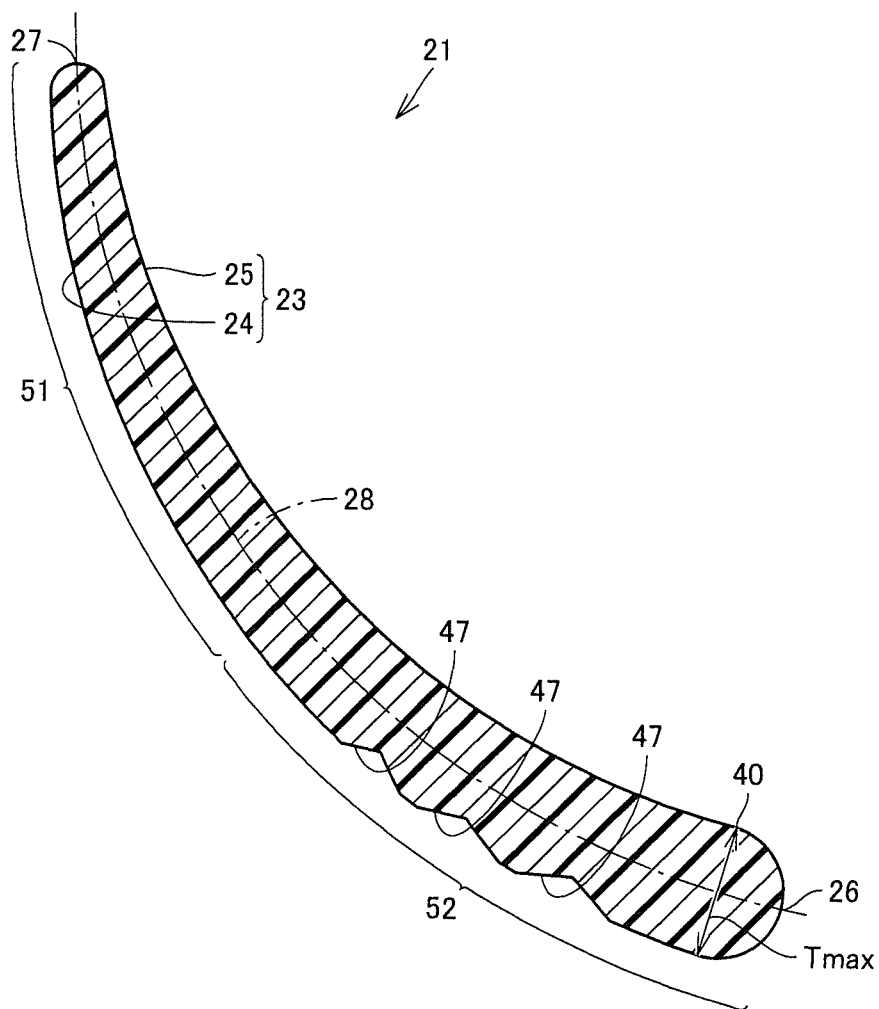


FIG.28

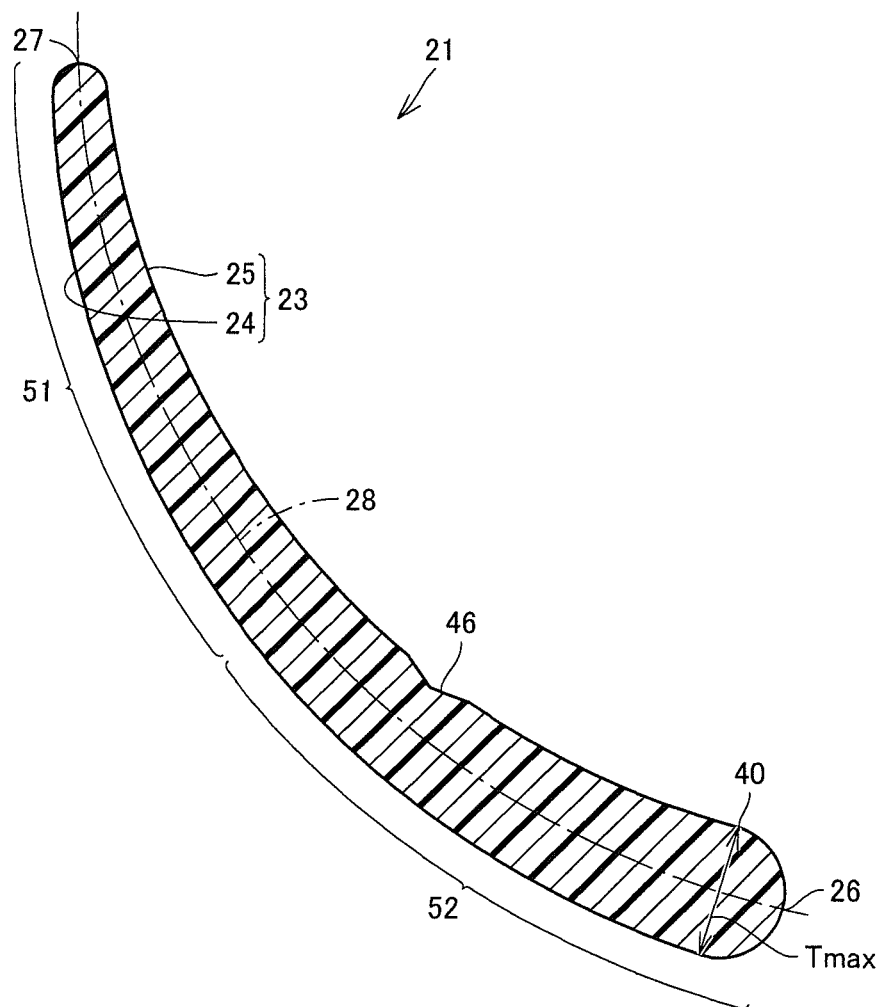


FIG.30

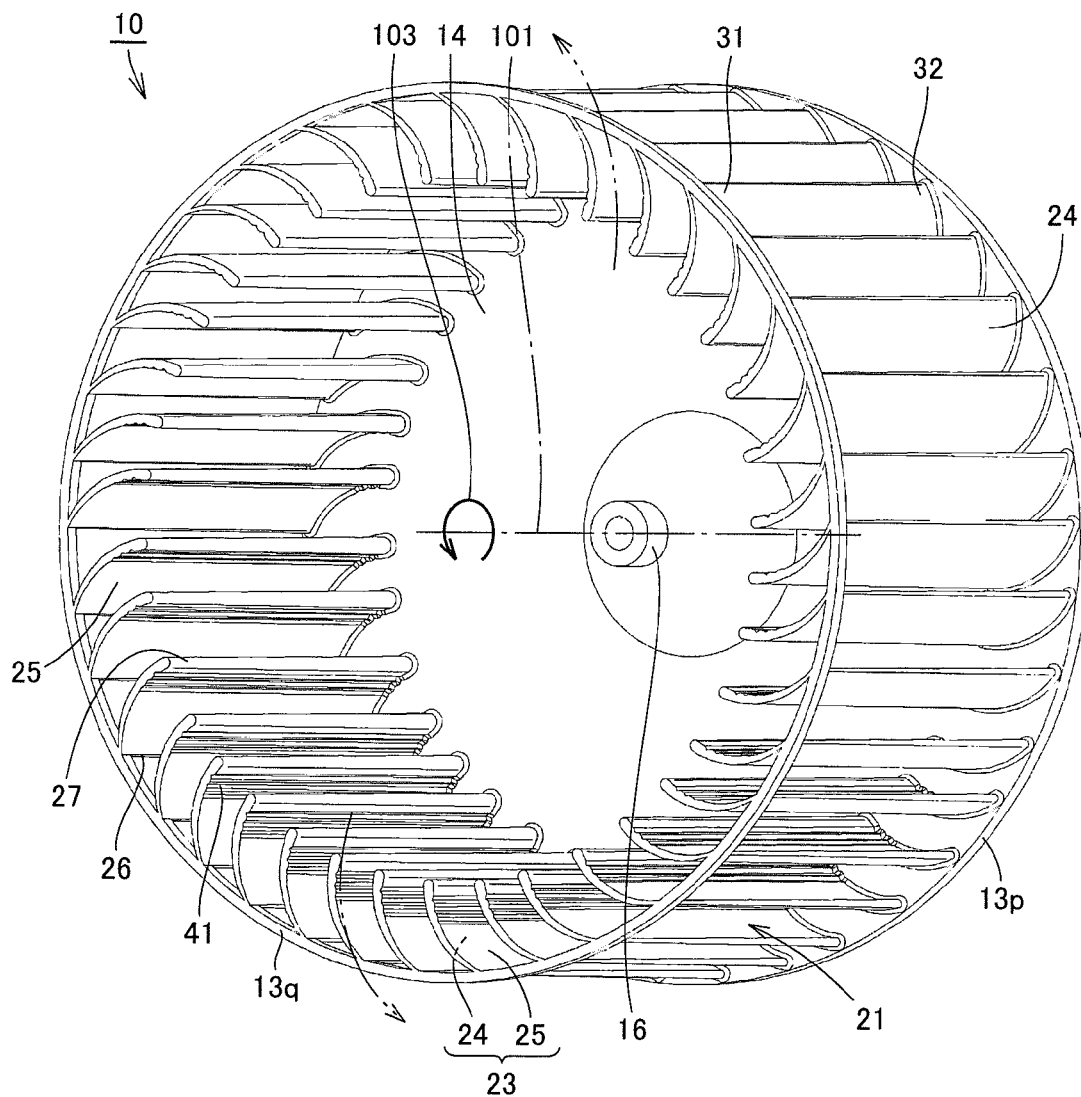


FIG.31

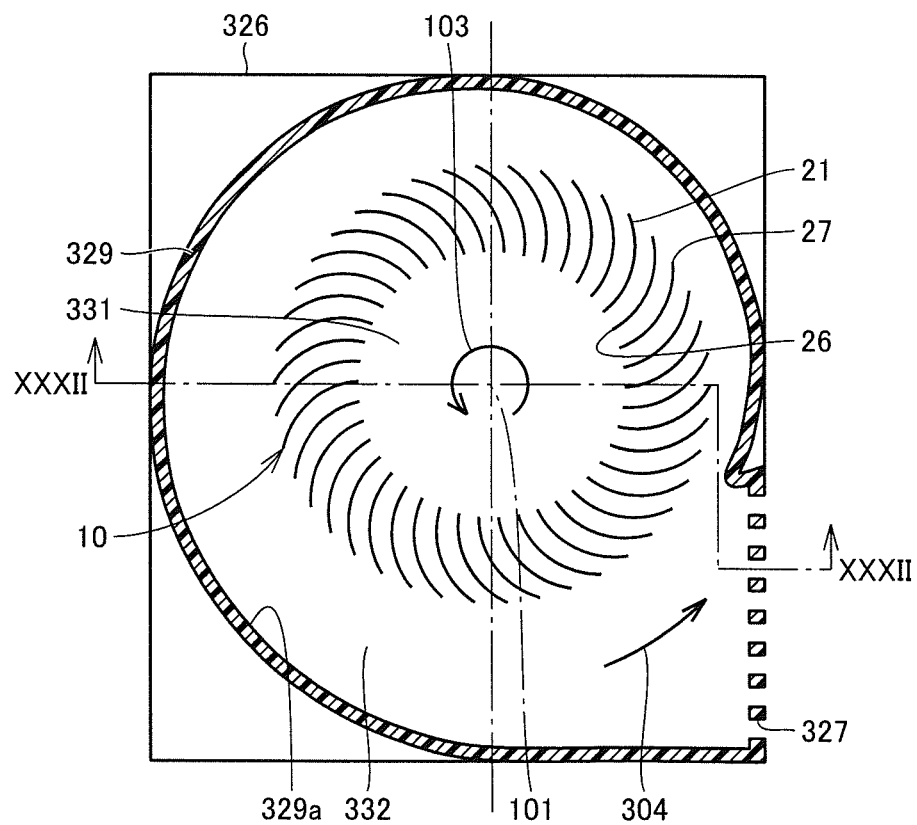


FIG.32

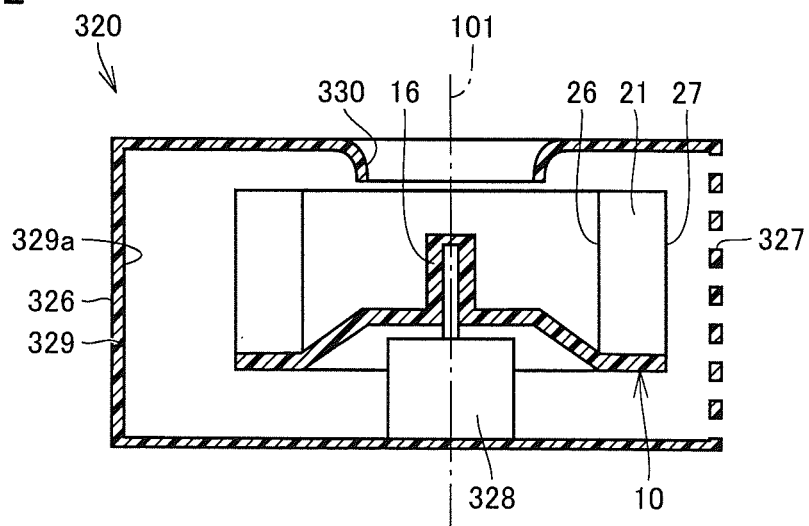
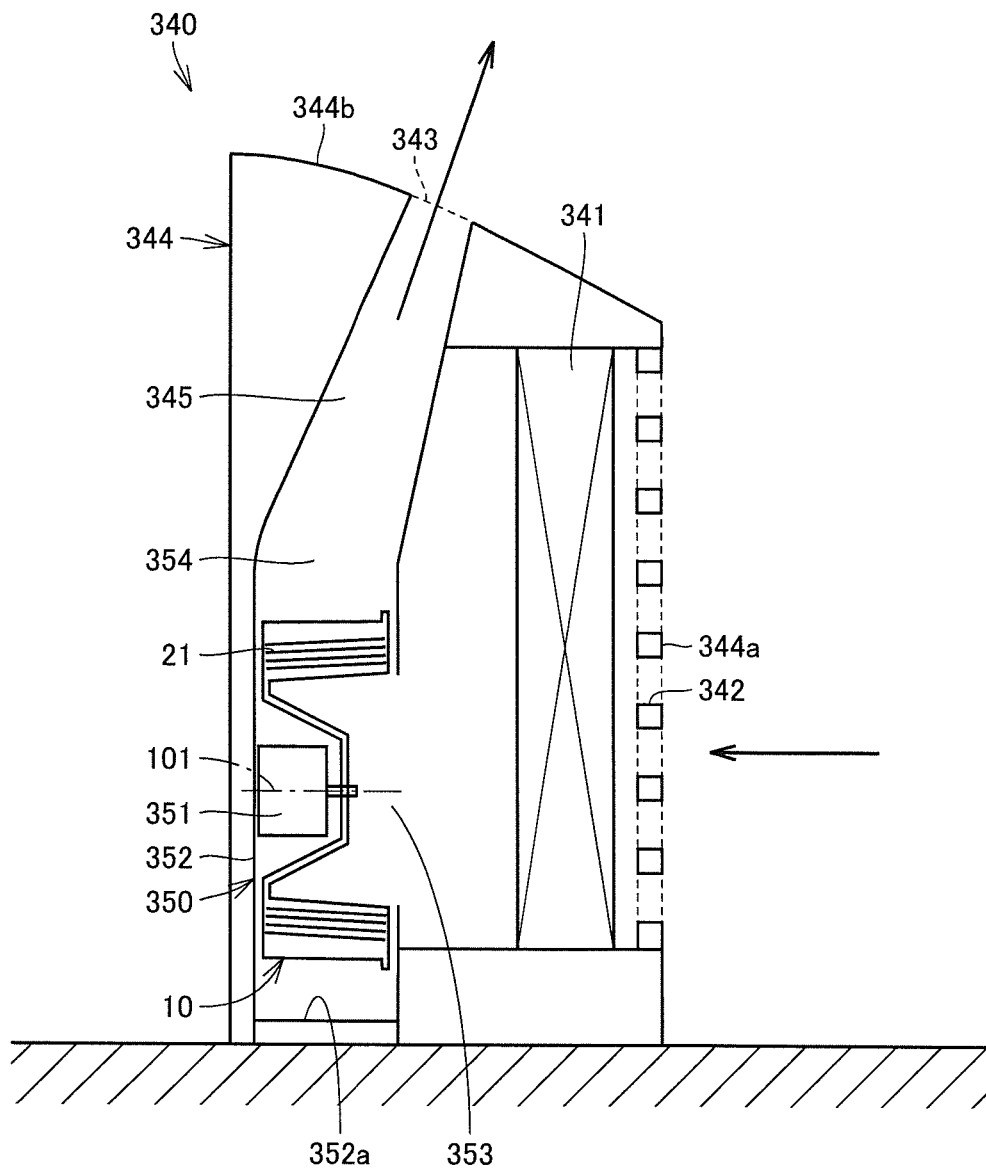


FIG.33



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FAN, MOLDING DIE, AND FLUID FEEDER**TECHNICAL FIELD**

This invention generally relates to a fan, a molding die, and a fluid feeder, and more particularly to such a fan as a cross-flow fan or a centrifugal fan, a molding die used for manufacturing the fan, and a fluid feeder including the fan.

BACKGROUND ART

With regard to a conventional fan, for example, Japanese Patent Laying-Open No. 2009-293616 (PTL 1) and Japanese Patent Laying-Open No. 2010-14123 (PTL 2) disclose a cross-flow fan aiming to suppress increase in input of a fan drive motor. The cross-flow fan disclosed in PTLs 1 and 2 has a blade curved toward a pressure surface side. In an edge portion on an outer circumferential side of the blade, a plurality of cut portions cut in a direction at a right angle from the edge portion on the outer circumferential side are formed at prescribed intervals.

CITATION LIST**Patent Literature**

PTL 1: Japanese Patent Laying-Open No. 2009-293616

PTL 2: Japanese Patent Laying-Open No. 2010-14123

SUMMARY OF INVENTION**Technical Problem**

In recent years, for conservation of global environment, further energy saving in home electric appliances has been desired. For example, it has been known that efficiency of electric appliances such as an air conditioner and an air cleaner greatly depends on efficiency of a blower contained therein. Therefore, in order to promote energy saving in electric appliances, air blow capability of a blower should be improved.

A cross-flow fan forming a planar blown flow in parallel to a rotation axis of a fan, a centrifugal fan sending air in a radial direction from a center of rotation of a fan, and the like are exemplified as fans used for a blower. In such a fan, an approach for increasing the number of fan blades is possible as general measures for improving air blow capability of the fan. According to this approach, an effect of increase in transmission of momentum to an air flow owing to viscosity on a blade surface and an effect of suppression of generation of a region where an air flow separates because of decrease in interval between adjacent fan blades are achieved. Consequently, good static pressure characteristics are realized and thus air blow capability of the fan can be improved.

In the case where the number of fan blades is increased, however, weight of the fan increases in correspondence with increase in the number of fan blades. Therefore, there is a concern that power consumption in a drive motor for the fan blade increases. In contrast, when the interval between adjacent fan blades is made smaller, resistance in a flow path between the blades also increases, which is also a factor for increase in power consumption in the drive motor.

On the other hand, an approach to adopt a fan blade having an aerofoil cross-section is possible as different measures for improvement in air blow capability of the fan. The aerofoil cross-section refers to such a cross-sectional shape that a large-thickness portion at which a fan blade has a greatest

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thickness is present closer to any one of an inner edge portion and an outer edge portion of the fan blade. In this case, when air flows from any one of the inner edge portion and the outer edge portion where the large-thickness portion is present to the other of the inner edge portion and the outer edge portion, a shape of a flow path between adjacent fan blades becomes such an enlarging flow path that it gradually increases in size along a direction of a flow of air. As air flows through such an enlarging flow path, a pressure of the air flow is recovered in the downstream. Therefore, by setting the large-thickness portion at an optimal position, good static pressure characteristics can be realized without increase in the number of fan blades.

Therefore, an object of this invention is to solve the above-described problems, and to provide a fan achieving excellent air blow capability, a molding die, and a fluid feeder.

Solution to Problem

A fan according to this invention includes a plurality of vane portions provided at a distance from one another in a circumferential direction. The vane portion has an inner edge portion arranged on an inner circumferential side and an outer edge portion arranged on an outer circumferential side. The vane portion has a blade surface formed, which extends between the inner edge portion and the outer edge portion and is constituted of a positive pressure surface and a negative pressure surface. The positive pressure surface is arranged on a side of a direction of rotation of the fan and the negative pressure surface is arranged on a back side of the positive pressure surface. As the fan rotates, a fluid flow which flows between the inner edge portion and the outer edge portion is generated over the blade surface. The vane portion has such a blade cross-sectional shape that a large-thickness portion at which a thickness between the positive pressure surface and the negative pressure surface is greatest is arranged closer to any one of the inner edge portion and the outer edge portion when it is cut in a plane orthogonal to a rotation axis of the fan. A recess recessed in the blade surface is formed at a position closer to any one of the inner edge portion and the outer edge portion where the large-thickness portion is arranged, than to any the other of the inner edge portion and the outer edge portion.

According to the fan thus constructed, when a fluid flows between adjacent vane portions from any one of the inner edge portion and the outer edge portion where the large-thickness portion is arranged to the other of the inner edge portion and the outer edge portion, a pressure of the fluid flow is recovered and hence good static pressure characteristics can be obtained. Meanwhile, by forming a recess at a position closer to any one of the inner edge portion and the outer edge portion where the large-thickness portion is arranged, weight of the fan can be reduced while strength of the vane portion is ensured. Here, as a vortex of the fluid flow (a secondary flow) is generated in the recess, the fluid flow (a main flow) which passes over the blade surface flows along the outside of the vortex generated in the recess. Therefore, in spite of formation of the recess in the vane portion, the fluid can flow along the blade surface in a stable manner. Consequently, a fan realizing high air blow capability can be obtained.

Further preferably, the recess is formed in the positive pressure surface. According to the fan thus constructed, on the positive pressure surface, a higher pressure is applied to the fluid flow which passes over the blade surface, than on the negative pressure surface. Therefore, in spite of formation of the recess in the positive pressure surface, the fluid can flow along the blade surface in a stable manner.

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Further preferably, the recess is formed such that the vane portion at a position where the recess is formed has a thickness equal to or greater than an average value of a thickness of the vane portion between the inner edge portion and the outer edge portion. According to the fan thus constructed, a thickness of the vane portion at a position where the recess is formed can be prevented from becoming too small and strength of the vane portion can be ensured.

Further preferably, a plurality of recesses are formed as being aligned in a direction of connection of the inner edge portion and the outer edge portion to each other. According to the fan thus constructed, weight of the fan can significantly be reduced while the fluid flow over the blade surface is stabilized by making a cross-sectional area of each recess recessed in the blade surface smaller.

Further preferably, the recess is formed to extend from one end to the other end of the vane portion in the direction of the rotation axis of the fan. According to the fan thus constructed, weight of the fan can significantly be reduced while the fluid flow over the blade surface is stabilized by making a cross-sectional area of the recess recessed in the blade surface smaller.

Further preferably, when cut in the plane orthogonal to the rotation axis of the fan, the vane portion has a cross-sectional area increasing from one end toward the other end. The recess is formed such that a cross-sectional area of the recess recessed in the blade surface is greater on a side of the other end than on a side of one end. According to the fan thus constructed, weight of the fan can significantly be reduced while strength of the vane portion is ensured.

Further preferably, the plurality of vane portions include a first vane portion and a second vane portion different in form of the recess formed in the vane portion.

According to the fan thus constructed, as a form of the recess formed in the vane portion is different, a shape, a size, or the number of vortexes of the fluid flow formed in the recess is different between the first vane portion and the second vane portion. In this case, since the fluid flow which flows along the outside of the vortex is also affected by the shape, the size, or the number of vortexes, a direction or a velocity of the fluid flow in the downstream of the recess can be varied between the first vane portion and the second vane portion. Thus, frequencies of passing sounds of the vane portions can be distributed and noise in connection with drive of the fan can be suppressed.

Further preferably, the vane portion has a thickness increasing from any one of the inner edge portion and the outer edge portion toward the large-thickness portion and decreasing from the large-thickness portion toward any the other of the inner edge portion and the outer edge portion. According to the fan thus constructed, an enlarging flow path of which flow path cross-section increases from any one of the inner edge portion and the outer edge portion where the large-thickness portion is arranged to the other of the inner edge portion and the other edge portion can be obtained between the adjacent vane portions. Thus, a pressure of the fluid flow which flows through the enlarging flow path can be recovered.

Further preferably, the large-thickness portion is arranged closer to the inner edge portion than to the outer edge portion. The recess is formed as being recessed in the positive pressure surface at a position closer to the inner edge portion than to the outer edge portion. An additional recess is further formed in the vane portion. The additional recess is formed as being recessed in the negative pressure surface at a position closer to the outer edge portion than to the inner edge portion. According to the fan thus constructed, weight of the fan can further be

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reduced by forming the additional recess. Here, as a vortex of the fluid flow is generated in the additional recess, the fluid can smoothly flow along the negative pressure surface. In addition, since the fluid which flows over the negative pressure surface is not affected by centrifugal force as compared with the positive pressure surface, accumulation of dust in the additional recess can be suppressed.

Further preferably, the additional recess recessed in the negative pressure surface is smaller in depth than the recess recessed in the positive pressure surface. According to the fan thus constructed, a thickness of the vane portion can be prevented from becoming too small on an outer edge portion side distant from the large-thickness portion and hence strength of the vane portion can be ensured.

Further preferably, in the inside of the plurality of vane portions aligned in the circumferential direction, an inner space is formed, and on the outside thereof, an outer space is formed. The fan described in any part above is a cross-flow fan for taking a fluid from the outer space on one side with respect to the rotation axis into the inner space when viewed in the direction of the rotation axis of the fan and sending the taken fluid to the outer space on the other side with respect to the rotation axis. According to the fan thus constructed, a cross-flow fan having light weight and realizing high air blow capability can be obtained.

Further preferably, in the inside of the plurality of vane portions aligned in the circumferential direction, an inner space is formed, and on the outside thereof, an outer space is formed. The fan described in any part above is a centrifugal fan for sending a fluid from the inner space to the outer space. The large-thickness portion is arranged closer to the inner edge portion than to the outer edge portion. According to the fan thus constructed, a centrifugal fan having light weight and realizing high air blow capability can be obtained.

Further preferably, the fan described in any part above is formed from resin. According to the fan thus constructed, a fan made of resin, which has light weight and exhibits high air blow capability, can be obtained.

A molding die according to this invention is used for molding the fan described in any part above. According to the molding die thus constructed, a fan made of resin can be manufactured.

A fluid feeder according to this invention includes a blower constituted of the fan described in any part above and a drive motor coupled to the fan to rotate the plurality of vane portions. According to the fluid feeder thus constructed, power consumption in the drive motor can be reduced while high air blow capability is maintained.

Advantageous Effects of Invention

As described above, according to this invention, a fan realizing high air blow capability, a molding die, and a fluid feeder can be provided.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view showing a cross-flow fan in a first embodiment of this invention.

FIG. 2 is a perspective view showing one of impellers constituting the cross-flow fan in FIG. 1.

FIG. 3 is a cross-sectional view showing the cross-flow fan along the line III-III in FIG. 1.

FIG. 4 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 1.

FIG. 5 is a cross-sectional view showing an air conditioner in which the cross-flow fan in FIG. 1 is employed.

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FIG. 6 is a cross-sectional view showing in an enlarged view, a portion in the vicinity of an outlet port of the air conditioner in FIG. 5.

FIG. 7 is a cross-sectional view showing an air flow generated in the vicinity of the outlet port of the air conditioner in FIG. 5.

FIG. 8 is a cross-sectional view showing a molding die used in manufacturing of the cross-flow fan in FIG. 1.

FIG. 9 is a cross-sectional view showing in an enlarged view, an area surrounded by a chain double dotted line IX in FIG. 7.

FIG. 10 is a diagram schematically representing an air flow path in the area shown in FIG. 9.

FIG. 11 is a cross-sectional view schematically representing a phenomenon that takes place on a blade surface of the fan blade in a downstream-side region shown in FIG. 7.

FIG. 12 is a cross-sectional view schematically representing a phenomenon that takes place on the blade surface of the fan blade in an upstream-side region shown in FIG. 7.

FIG. 13 is a graph showing relation between an air flow rate of the cross-flow fan and power consumption (input) in a drive motor.

FIG. 14 is a graph showing static pressure characteristics of the cross-flow fan.

FIG. 15 is a cross-sectional view showing a variation of the fan blade shown in FIG. 11.

FIG. 16 is a perspective view showing the fan blade in FIG. 2.

FIG. 17 is a cross-sectional view showing the fan blade along the line XVII-XVII in FIG. 16.

FIG. 18 is a cross-sectional view showing the fan blade along the line XVIII-XVIII in FIG. 16.

FIG. 19 is a perspective view showing a first variation of the cross-flow fan in FIG. 1.

FIG. 20 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 19.

FIG. 21 is a cross-sectional view showing a downstream-side region in the case where the cross-flow fan in FIG. 19 is applied to an air conditioner.

FIG. 22 is a perspective view showing a second variation of the cross-flow fan in FIG. 1.

FIG. 23 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 22.

FIG. 24 is a cross-sectional view showing a first variation of the fan blade shown in FIG. 23.

FIG. 25 is a cross-sectional view showing a second variation of the fan blade shown in FIG. 23.

FIG. 26 is a cross-sectional view showing a third variation of the fan blade shown in FIG. 23.

FIG. 27 is a cross-sectional view showing a fourth variation of the fan blade shown in FIG. 23.

FIG. 28 is a cross-sectional view showing a fifth variation of the fan blade shown in FIG. 23.

FIG. 29 is a cross-sectional view showing a third variation of the cross-flow fan in FIG. 1.

FIG. 30 is a perspective view showing a centrifugal fan in a third embodiment of this invention.

FIG. 31 is a cross-sectional view showing a blower in which the centrifugal fan in FIG. 30 is employed.

FIG. 32 is a cross-sectional view showing the blower along the line XXXII-XXXII in FIG. 31.

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FIG. 33 is a cross-sectional view showing an air cleaner in which the centrifugal fan in FIG. 30 is employed.

DESCRIPTION OF EMBODIMENTS

An embodiment of this invention will be described with reference to the drawings. It is noted that the same or corresponding members have the same numbers allotted in the drawings referred to below.

First Embodiment

(Description of Basic Structure of Cross-Flow Fan)

FIG. 1 is a perspective view showing a cross-flow fan in a first embodiment of this invention. FIG. 2 is a perspective view showing one of impellers constituting the cross-flow fan in FIG. 1. FIG. 3 is a cross-sectional view showing the cross-flow fan along the line III-III in FIG. 1.

Referring to FIGS. 1 to 3, a cross-flow fan 100 in the present embodiment has a plurality of fan blades 21. Cross-flow fan 100 has appearance in a substantially cylindrical shape as a whole and the plurality of fan blades 21 are arranged around a circumferential surface of the substantially cylindrical shape. Cross-flow fan 100 is integrally formed from resin. Cross-flow fan 100 rotates in a direction shown with an arrow 103 around a virtual central axis 101 shown in the figure.

Cross-flow fan 100 is a fan sending air in a direction orthogonal to central axis 101 which is a rotation axis, by using the plurality of rotating fan blades 21. Cross-flow fan 100 is such a fan that, when viewed in an axial direction of central axis 101, air is taken into an inner space of the fan from an outer space on one side with respect to central axis 101 and then taken air is sent to the outer space on the other side with respect to central axis 101. Cross-flow fan 100 forms an air flow which flows in a direction intersecting central axis 101 in a plane orthogonal to central axis 101. Cross-flow fan 100 forms a planar blown flow in parallel to central axis 101.

Cross-flow fan 100 is used at the number of revolutions in a range of low Reynolds numbers applied to fans in home electric appliances or the like.

Cross-flow fan 100 is constructed in such a manner that a plurality of impellers 12 aligned in an axial direction of central axis 101 are combined. In each impeller 12, the plurality of fan blades 21 are provided at a distance from one another in a circumferential direction around central axis 101.

Cross-flow fan 100 further has an outer circumferential frame 13 serving as a support portion. Outer circumferential frame 13 has a ring shape as extending annularly around central axis 101. Outer circumferential frame 13 has an end surface 13a and an end surface 13b. End surface 13a is formed to face one direction along the axial direction of central axis 101. End surface 13b is arranged on a back side of end surface 13a and formed to face the other direction along the axial direction of central axis 101.

Outer circumferential frame 13 is provided to lie between adjacent impellers 12 in the axial direction of central axis 101.

Attention being paid to an impeller 12A and an impeller 12B in FIG. 1 arranged adjacent to each other, the plurality of fan blades 21 provided in impeller 12A are formed to be erected on end surface 13a and to extend like a plate along the axial direction of central axis 101. The plurality of fan blades 21 provided in impeller 12B are formed to be erected on end surface 13b and to extend like a plate along the axial direction of central axis 101.

In a process for manufacturing cross-flow fan 100, impeller 12 shown in FIG. 2 is manufactured with resin molding. In

addition, a form of cross-flow fan **100** in FIG. 1 is obtained by connecting the plurality of obtained impellers **12** to one another.

FIG. 3 shows a blade cross-section of fan blades **21** in the case where they are cut in a plane orthogonal to central axis **101** which is the rotation axis of cross-flow fan **100**.

Referring to FIGS. 2 and 3, fan blade **21** has an inner edge portion **27** and an outer edge portion **26**. Inner edge portion **27** is arranged on an inner circumferential side of fan blade **21**. Outer edge portion **26** is arranged on an outer circumferential side of fan blade **21**. Fan blade **21** is formed as being inclined in a circumferential direction around central axis **101** from inner edge portion **27** toward outer edge portion **26**. Fan blade **21** is formed as being inclined in a direction of rotation of cross-flow fan **100** from inner edge portion **27** toward outer edge portion **26**.

In fan blade **21**, a blade surface **23** constituted of a positive pressure surface **25** and a negative pressure surface **24** is formed. Positive pressure surface **25** is arranged on a side in a direction of rotation of cross-flow fan **100** and negative pressure surface **24** is arranged on a back side of positive pressure surface **25**. As an air flow is generated over blade surface **23** during rotation of cross-flow fan **100**, such pressure distribution that pressure is relatively high on positive pressure surface **25** and it is relatively low on negative pressure surface **24** is produced. Fan blade **21** has a blade cross-section curved as a whole between inner edge portion **27** and outer edge portion **26** such that a positive pressure surface **25** side is concave and a negative pressure surface **24** side is convex. Fan blade **21** is formed to have a thin blade cross-section between inner edge portion **27** and outer edge portion **26**.

FIG. 4 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 1. Referring to FIG. 4, the figure shows a centerline **28** with respect to a direction of thickness (a direction connecting positive pressure surface **25** and negative pressure surface **24** to each other) of the blade cross-section of fan blade **21**.

Centerline **28** extends through the blade cross-section to divide the blade cross-section of fan blade **21** into the positive pressure surface **25** side and the negative pressure surface **24** side. Centerline **28** may be defined by a single arc or by combination of a plurality of arcs different in curvature. Fan blade **21** has inner edge portion **27** at a tip end where centerline **28** extends toward the inner circumferential side and outer edge portion **26** at a tip end where centerline **28** extends toward the outer circumferential side. Centerline **28** extends as being curved between inner edge portion **27** and outer edge portion **26**. It is noted that, at a position where a recess **41** which will be described later is formed, centerline **28** is shown to extend through a central position between positive pressure surface **25** and negative pressure surface **24** in the absence of recess **41** as shown with a dotted line in FIG. 4.

Positive pressure surface **25** and negative pressure surface **24** each extend as being curved between inner edge portion **27** and outer edge portion **26**. In the case where a length between positive pressure surface **25** and negative pressure surface **24** is referred to as a thickness of fan blade **21**, fan blade **21** has a thickness **T** at an arbitrary position between inner edge portion **27** and outer edge portion **26**. In the present embodiment, thickness **T** of fan blade **21** is zero at inner edge portion **27** and outer edge portion **26**. Thickness **T** of the fan blade continuously changes between inner edge portion **27** and outer edge portion **26**.

On blade surface **23** of fan blade **21**, an inner circumferential side region **51** closer to inner edge portion **27** than to outer edge portion **26** and an outer circumferential side region **52**

closer to outer edge portion **26** than to inner edge portion **27** are defined. Namely, in a direction of extension of centerline **28** connecting inner edge portion **27** and outer edge portion **26** to each other, inner circumferential side region **51** is arranged on an inner edge portion **27** side and outer circumferential side region **52** is arranged on an outer edge portion **26** side. A length of blade surface **23** (positive pressure surface **25** or negative pressure surface **24**) between a position of boundary between inner circumferential side region **51** and outer circumferential side region **52** and inner edge portion **27** is equal to a length of blade surface **23** (positive pressure surface **25** or negative pressure surface **24**) between the position of boundary between inner circumferential side region **51** and outer circumferential side region **52** and outer edge portion **26**.

Fan blade **21** has a large-thickness portion **40**. Fan blade **21** has a greatest thickness T_{max} at large-thickness portion **40** on centerline **28** connecting inner edge portion **27** and outer edge portion **26** to each other. Thickness **T** of fan blade **21** increases from inner edge portion **27** toward large-thickness portion **40**, attains to maximum at large-thickness portion **40**, and then decreases from large-thickness portion **40** toward outer edge portion **26**.

Large-thickness portion **40** is arranged closer to any one of inner edge portion **27** and outer edge portion **26**. In the present embodiment, large-thickness portion **40** is arranged closer to inner edge portion **27**, of inner edge portion **27** and outer edge portion **26**. Large-thickness portion **40** is arranged in inner circumferential side region **51** closer to inner edge portion **27** than to outer edge portion **26**. Large-thickness portion **40** is arranged adjacent to inner edge portion **27**. Large-thickness portion **40** is arranged at a position where a length of blade surface **23** between inner edge portion **27** and large-thickness portion **40** is smaller than a length of blade surface **23** between large-thickness portion **40** and the position of boundary between inner circumferential side region **51** and outer circumferential side region **52**. Fan blade **21** has such a blade cross-section that a thickness is relatively great on the inner circumferential side and relatively small on the outer circumferential side as a whole.

Fan blade **21** has an aerofoil cross-section having large-thickness portion **40** arranged closer to any one of inner edge portion **27** and outer edge portion **26** when it is cut in a plane orthogonal to central axis **101**.

Referring to FIGS. 2 to 4, recess **41** is formed in fan blade **21**. Recess **41** is formed to be recessed in blade surface **23**. Recess **41** is formed at a position closer to inner edge portion **27** where large-thickness portion **40** is arranged, than to outer edge portion **26**, that is, in inner circumferential side region **51**. No recess is formed at a position closer to outer edge portion **26** than to inner edge portion **27** where large-thickness portion **40** is arranged, that is, in outer circumferential side region **52**.

In the present embodiment, recess **41** is formed in positive pressure surface **25**. No recess is formed in negative pressure surface **24**. Recess **41** is formed in any one of positive pressure surface **25** and negative pressure surface **24**. In positive pressure surface **25**, blade surface **23** becomes discontinuous at a position between inner edge portion **27** and outer edge portion **26**, where recess **41** is formed. In negative pressure surface **24** where no recess is formed, blade surface **23** extends continuously between inner edge portion **27** and outer edge portion **26**.

As shown in FIG. 2, fan blade **21** extends between one end **31** and the other end **32** in the axial direction of central axis **101**. In the form of cross-flow fan **100** shown in FIG. 1, one end **31** is connected to end surface **13b** of outer circumferen-

tial frame **13**, and the other end **32** is connected to end surface **13a** of outer circumferential frame **13**.

Recess **41** is in a shape of a groove extending along the axial direction of central axis **101**. Recess **41** is formed to extend continuously between one end **31** and the other end **32** of fan blade **21** in the axial direction of central axis **101**. Recess **41** is formed to extend linearly between one end **31** and the other end **32** of fan blade **21** in the axial direction of central axis **101**.

Recess **41** has a triangular cross-section when cut in a plane orthogonal to central axis **101**. Recess **41** is not limited to such a shape, and for example, it may have a trapezoidal or arc-shaped cross-section.

A plurality of recesses **41** (**41A**, **41B**, **41C**) are formed in fan blade **21**. The plurality of recesses **41** are formed in any one surface of positive pressure surface **25** and negative pressure surface **24**, as being aligned in a direction of connection of inner edge portion **27** and outer edge portion **26** to each other. The plurality of recesses **41** are formed in positive pressure surface **25**, as being aligned in the direction of connection of inner edge portion **27** and outer edge portion **26** to each other.

Recess **41A** is arranged closest to inner edge portion **27**, recess **41C** is arranged most distant from inner edge portion **27**, and recess **41B** is arranged between recess **41A** and recess **41C**. Recess **41A**, recess **41B**, and recess **41C** are different from one another in cross-sectional shape. Recess **41A**, recess **41B**, and recess **41C** are different from one another in groove depth. The plurality of recesses **41** are formed such that recess **41** arranged more distant from inner edge portion **27** is smaller in groove depth. Recess **41A**, recess **41B**, and recess **41C** are different from one another in width of opening in blade surface **23**.

Referring to FIGS. **1** to **3**, the plurality of fan blades **21** have an identical blade cross-section. In the case where fan blades **21** are rotated around central axis **101**, blade surfaces **23** of the plurality of fan blades **21** overlap one another. The plurality of fan blades **21** are aligned such that a pitch between adjacent fan blades **21** is random. Such a random pitch is realized, for example, by arranging the plurality of fan blades **21** at irregular intervals in accordance with random number normal distribution.

A plurality of impellers **12** are formed such that alignment of fan blades **21** is the same among them. Namely, an interval at which the plurality of fan blades **21** are aligned in each impeller **12** and an order of fan blades **21** aligned at those intervals are the same among the plurality of impellers **12**.

It is noted that the plurality of fan blades **21** may be aligned at regular pitches, without being limited to random pitches.

The plurality of impellers **12** are stacked such that a displacement angle **R** is produced between adjacent impellers **12** when viewed in the axial direction of central axis **101**. For example, attention being paid to impeller **12A**, impeller **12B**, and an impeller **12C** in FIG. **1** adjacently arranged in the order mentioned, impeller **12B** is stacked such that it is displaced with respect to impeller **12A** by displacement angle **R** around central axis **101** from a position where all fan blades **21** of impeller **12A** and impeller **12B** overlap in the axial direction of central axis **101**. In addition, impeller **12C** is stacked such that it is displaced with respect to impeller **12B** by displacement angle **R** (**2R** when viewed from impeller **12A**) around central axis **101** from a position where all fan blades **21** of impeller **12B** and impeller **12C** overlap in the axial direction of central axis **101**.

(Description of Structure of Air Conditioner and Molding Die)

FIG. **5** is a cross-sectional view showing an air conditioner in which the cross-flow fan in FIG. **1** is employed. Referring to FIG. **5**, an air conditioner **210** includes an indoor unit **220** placed in a room and provided with an indoor heat exchanger **229** and a not-shown outdoor unit placed outside the room and provided with an outdoor heat exchanger and a compressor. Indoor unit **220** and the outdoor unit are connected to each other by a pipe for circulating a refrigerant gas between indoor heat exchanger **229** and the outdoor heat exchanger.

Indoor unit **220** has a blower **215**. Blower **215** has cross-flow fan **100**, a not-shown drive motor for rotating cross-flow fan **100**, and a casing **222** for generating a prescribed air current along with rotation of cross-flow fan **100**.

Casing **222** has a cabinet **222A** and a front panel **222B**. Cabinet **222A** is supported on a wall surface in the room, and front panel **222B** is removably attached to cabinet **222A**. An outlet port **225** is formed in a gap between a lower end portion of front panel **222B** and a lower end portion of cabinet **222A**. Outlet port **225** is formed in a substantially rectangular shape extending in a width direction of indoor unit **220** and provided to face down forward. An upper surface of front panel **222B** has an intake port **224** formed in a lattice shape.

At a position opposed to front panel **222B**, an air filter **228** is provided to catch and remove dust included in air sucked through intake port **224**. A not-shown air filter cleaning apparatus is provided in a space formed between front panel **222B** and air filter **228**. The air filter cleaning apparatus automatically removes dust accumulated in air filter **228**.

An air-blow passage **226** through which air flows from intake port **224** toward outlet port **225** is formed inside casing **222**. Outlet port **225** is provided with a vertical louver **232** capable of changing an angle of blowing in right and left directions and a plurality of lateral louvers **231** capable of changing an angle of vertical blowing in forward and upward, horizontal, forward and downward, and downward directions.

Indoor heat exchanger **229** is arranged between cross-flow fan **100** and air filter **228** in a path of air-blow passage **226**. Indoor heat exchanger **229** has not-shown winding refrigerant pipes arrayed in a plurality of stages in a vertical direction and a plurality of rows in a front-back direction in parallel to one another. Indoor heat exchanger **229** is connected to the compressor of the outdoor unit placed outside the room, and a refrigeration cycle is operated by drive of the compressor. As the refrigeration cycle is operated, indoor heat exchanger **229** is cooled to a temperature lower than ambient temperature during cooling operation, and indoor heat exchanger **229** is heated to a temperature higher than ambient temperature during heating operation.

FIG. **6** is a cross-sectional view showing in an enlarged view, a portion in the vicinity of the outlet port of the air conditioner in FIG. **5**. Referring to FIGS. **5** and **6**, casing **222** has a front wall portion **251** and a rear wall portion **252**. Front wall portion **251** and rear wall portion **252** are arranged to face each other at a distance from each other.

In the path of air-blow passage **226**, cross-flow fan **100** is arranged to be located between front wall portion **251** and rear wall portion **252**. Front wall portion **251** has a projection **253** formed, which projects toward an outer circumferential surface of cross-flow fan **100** to minimize a gap between cross-flow fan **100** and front wall portion **251**. Rear wall portion **252** has a projection **254** formed, which projects toward the outer circumferential surface of cross-flow fan **100** to minimize a gap between cross-flow fan **100** and rear wall portion **252**.

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Casing 222 has an upper guide portion 256 and a lower guide portion 257. Air-blow passage 226 is defined by upper guide portion 256 and lower guide portion 257 in the air flow downstream of cross-flow fan 10.

Upper guide portion 256 and lower guide portion 257 are continuous from front wall portion 251 and rear wall portion 252 respectively and extend toward outlet port 225. Upper guide portion 256 and lower guide portion 257 are formed such that air sent from cross-flow fan 100 is curved with upper guide portion 256 being located on the inner circumferential side and lower guide portion 257 being located on the outer circumferential side and guided down forward. Upper guide portion 256 and lower guide portion 257 are formed such that a cross-sectional area of air-blow passage 226 increases from cross-flow fan 100 toward outlet port 225.

According to the present embodiment, front wall portion 251 and upper guide portion 256 are formed to be integral with front panel 222B. Rear wall portion 252 and lower guide portion 257 are formed to be integral with cabinet 222A.

FIG. 7 is a cross-sectional view showing an air flow generated in the vicinity of the outlet port of the air conditioner in FIG. 5. Referring to FIGS. 5 to 7, on the path of air-blow passage 226, an upstream-side outer space 246 is formed in the air flow upstream of cross-flow fan 100, an inner space 247 is formed in the inside of cross-flow fan 100 (on the inner circumferential side of the plurality of fan blades 21 aligned in the circumferential direction), and a downstream-side outer space 248 is formed in the air flow downstream of cross-flow fan 100.

During rotation of cross-flow fan 100, an air flow 261 passing over blade surface 23 of fan blade 21 from upstream-side outer space 246 toward inner space 247 is formed in an upstream-side region 241 of air-blow passage 226 with projections 253, 254 serving as a boundary, and air flow 261 passing over blade surface 23 of fan blade 21 from inner space 247 toward downstream-side outer space 248 is formed in a downstream-side region 242 of air-blow passage 226 with projections 253, 254 serving as a boundary. Here, a forced vortex 262 of an air flow is formed at a position adjacent to front wall portion 251.

Though an air conditioner has been described by way of example in the present embodiment, other than this, the cross-flow fan according to the present invention is also applicable to such apparatuses for sending a fluid as an air cleaner, a humidifier, a cooling apparatus, and a ventilating apparatus.

FIG. 8 is a cross-sectional view showing a molding die used in manufacturing of the cross-flow fan in FIG. 1. Referring to FIG. 8, a molding die 160 has a stationary die 164 and a movable die 162. Stationary die 164 and movable die 162 define a cavity 166 formed in a shape substantially equal to that of cross-flow fan 100, into which fluid resin is injected.

Molding die 160 may be provided with a not-shown heater for enhancing fluidity of the resin injected into cavity 166. Such placement of the heater is effective particularly when synthetic resins having enhanced strengths such as AS (a copolymer compound of acrylonitrile and styrene) resin filled with glass fibers are employed.

It is noted that a centrifugal fan 10 in a third embodiment which will be described later is also manufactured with a die similar in structure to molding die 160 in FIG. 8.

(Detailed Description of Function and Effect)

In succession, a function and effect achieved by cross-flow fan 100 in the present embodiment will be described assuming a case where cross-flow fan 100 is applied to the air conditioner in FIGS. 5 to 7.

FIG. 9 is a cross-sectional view showing in an enlarged view, an area surrounded by a chain double dotted line IX in

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FIG. 7. FIG. 10 is a diagram schematically representing an air flow path in the area shown in FIG. 9.

Referring to FIGS. 9 and 10, in downstream-side region 242, when an air flow from inner space 247 toward downstream-side outer space 248 is formed (see FIG. 6), an air flow which flows from inner edge portion 27, passes over blade surface 23, and flows out of outer edge portion 26 is generated in an air flow path 55 formed between adjacent fan blades 21.

In cross-flow fan 100 in the present embodiment, large-thickness portion 40 where thickness of fan blade 21 is greatest is arranged closer to inner edge portion 27, of inner edge portion 27 and outer edge portion 26. Therefore, air flow path 55 formed between adjacent fan blades 21 has a flow path area S1 relatively small on the inner circumferential side and a flow path area S2 great on the outer circumferential side. According to such a construction, air from inner edge portion 27 toward outer edge portion 26 flows through an enlarging flow path of which flow path cross-section increases from upstream to downstream.

A pressure and a velocity of an air flow on the inner circumferential side of air flow path 55 are defined as P1 and V1, respectively, a pressure and a velocity of an air flow on the outer circumferential side of air flow path 55 are defined as P2 and V2, respectively, and a pressure in downstream-side outer space 248 is defined as P3. In this case, a velocity of an air flow becomes lower from the inner circumferential side toward the outer circumferential side of air flow path 55, while a pressure of the air flow increases ($V1 > V2$, $P1 < P2$). Thus, pressure P2 of the air flow sent through air flow path 55 between adjacent fan blades 21 becomes higher than pressure P3 in downstream-side outer space 248, and consequently static pressure characteristics of cross-flow fan 100 can be improved.

Since a flow velocity of an air flow is higher in downstream-side region 242 than in upstream-side region 241, separation of the air flow on blade surface 23 is more likely. In the present embodiment, by obtaining an effect of pressure recovery achieved by the enlarging flow path described above in downstream-side region 242 where such separation of the air flow is more likely, air blow capability of cross-flow fan 100 is significantly improved.

FIG. 11 is a cross-sectional view schematically representing a phenomenon that takes place on the blade surface of the fan blade in the downstream-side region shown in FIG. 7. Referring to FIG. 11, in downstream-side region 242, when an air flow from inner space 247 toward downstream-side outer space 248 is formed, an air flow which flows from inner edge portion 27, passes over blade surface 23, and flows out of outer edge portion 26 is generated over blade surface 23 of fan blade 21. Here, a clockwise vortex 105 of an air flow (secondary flow) is formed in recess 41 formed in positive pressure surface 25. Thus, an air flow 106 (main flow) which passes over blade surface 23 flows along the outside of vortex 105 generated in recess 41.

The reason why vortex 105 is formed in recess 41 is described. As described previously, cross-flow fan 100 is used at the number of revolutions in the range of low Reynolds numbers applied to a fan in home electric appliances or the like and a scale of recess 41 is smaller than at least thickness T of fan blade 21. Therefore, the Reynolds number of an air flow in recess 41 is smaller, for example, by the order of 10^{-1} with respect to the Reynolds number of an air flow around fan blade 21 for which a distance between inner edge portion 27 and outer edge portion 26 is considered in terms of a dimension scale. Therefore, an air flow within recess 41 becomes such a flow that viscosity is dominant, and a vortex in conformity with a recessed shape of recess 41 is formed.

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FIG. 12 is a cross-sectional view schematically representing a phenomenon that takes place on the blade surface of the fan blade in the upstream-side region shown in FIG. 7. Referring to FIG. 12, in upstream-side region 241, when an air flow from upstream-side outer space 246 toward inner space 247 is formed, an air flow which flows from outer edge portion 26, passes over blade surface 23, and flows out of inner edge portion 27 is generated over blade surface 23 of fan blade 21. Here, a counterclockwise vortex 107 of an air flow (secondary flow) is formed in recess 41 formed in positive pressure surface 25. Thus, an air flow 108 (main flow) which passes over blade surface 23 flows along the outside of vortex 107 generated in recess 41.

Namely, in cross-flow fan 100, as fan blade 21 moves from upstream-side region 241 to downstream-side region 242, a direction of an air flow over blade surface 23 is reversed, and accordingly a direction of rotation of a vortex generated in recess 41 is also reversed.

In the case where a fan blade having an aerofoil cross-section is adopted, weight per one fan blade increases. Therefore, weight of the fan as a whole increases and there is a concern that power consumption in the drive motor of the fan blade increases. In contrast, in cross-flow fan 100 in the present embodiment, by forming recess 41 in fan blade 21, weight of fan blade 21 can be reduced. Here, since recess 41 is formed at a position closer to inner edge portion 27 where large-thickness portion 40 is arranged, significant lowering in strength of fan blade 21 due to formation of recess 41 can be prevented.

On the other hand, there is a concern that separation of an air flow takes place on blade surface 23 due to formation of recess 41 in fan blade 21. In this regard, since a vortex flow is formed in recess 41, an air flow over blade surface 23 exhibits a behavior as if recess 41 were closed by the vortex. Therefore, air flows between adjacent fan blades 21, between inner edge portion 27 and outer edge portion 26, in a stable manner without causing separation. In particular in the present embodiment, a plurality of recesses 41 are formed in positive pressure surface 25. According to such a construction, weight of fan blade 21 can significantly be reduced while an air flow over blade surface 23 is stabilized by making a cross-sectional area of each recess 41 small.

In addition, vortex 105, 107 formed in recess 41 is formed in the form of projecting from blade surface 23 as shown in FIGS. 11 and 12, and air flow 106, 108 flows along the outside of vortex 105, 107. Therefore, fan blade 21 exhibits a behavior like a large-thickness blade of which blade cross-sectional shape is made thick at a position where vortex 105, 107 is formed. Thus, a function the same as in the case of narrowing an interval between adjacent fan blades 21 by increasing the number of fan blades 21 is substantially achieved and such a phenomenon that a back flow of an air flow takes place between adjacent fan blades 21 can be prevented.

Cross-flow fan 100 in the present embodiment shown in FIG. 1 and cross-flow fans in Comparative Example 1 and Comparative Example 2 were used to carry out examples described below. The cross-flow fan in Comparative Example 1 includes a fan blade having a thickness substantially uniform between inner edge portion 27 and outer edge portion 26. The cross-flow fan in Comparative Example 2 includes a fan blade having a blade cross-sectional shape the same as that of fan blade 21, however, the fan blade does not have a recess formed. Each cross-flow fan has such a size as a diameter of ϕ 100 mm and a length of 600 mm in the axial direction of central axis 101, and the form of providing the fan blade is also the same.

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FIG. 13 is a graph showing relation between an air flow rate of the cross-flow fan and power consumption (input) in a drive motor. Referring to FIG. 13, cross-flow fan 100 in the present embodiment shown in FIG. 1 and the cross-flow fans in Comparative Example 1 and Comparative Example 2 were applied to the air conditioner in FIGS. 5 to 7 and power consumption in the drive motor at each air flow rate was measured with the air flow rate being changed. As shown in the figure, cross-flow fan 100 in the present embodiment could achieve reduced power consumption in the motor with the air flow rate being the same, as compared with the cross-flow fans in Comparative Examples 1, 2, by reducing weight and improving air blow capability.

FIG. 14 is a graph showing static pressure characteristics of the cross-flow fan. Referring to FIG. 14, cross-flow fan 100 in the present embodiment shown in FIG. 1 and the cross-flow fans in Comparative Example 1 and Comparative Example 2 were applied to the air conditioner in FIGS. 5 to 7 and static pressure characteristics of each cross-flow fan (P: static pressure—Q: air flow rate) were determined. As shown in the figure, cross-flow fan 100 in the present embodiment could obtain static pressure characteristics better than those of the cross-flow fans in Comparative Examples 1, 2.

FIG. 15 is a cross-sectional view showing a variation of the fan blade shown in FIG. 11. Referring to FIG. 15, in the variation shown in the figure, in fan blade 21, in addition to recess 41 recessed in positive pressure surface 25, a recess 42 recessed in negative pressure surface 24 is formed. A counterclockwise vortex 111 of an air flow is formed in recess 42, and an air flow 112 which passes over negative pressure surface 24 flows along the outside of vortex 111 generated in recess 42.

In the case of using fan blade 21 thus constructed as well, by reducing weight of fan blade 21 by forming recesses 41, 42 and generating vortices 105, 111 in recesses 41, 42, air flows 106, 112 over blade surface 23 can be stabilized. In addition, as described above, fan blade 21 exhibits a behavior like a large-thickness blade of which blade cross-sectional shape is made thick at positions where vortices 105, 111 are formed. Here, if an effect of this larger thickness is excessive, air flow 112 over negative pressure surface 24 becomes unstable and there is a concern that separation takes place in the downstream of recess 42. On the other hand, since air flow 106 over positive pressure surface 25 receives a higher pressure from air flow path 55, the concern about occurrence of separation can be lessened in spite of the effect of a larger thickness of fan blade 21.

(Description of Detailed Structure of Cross-Flow Fan)

Referring to FIG. 4, recess 41 is formed such that fan blade 21 at the position where recess 41 is formed has a thickness equal to or greater than an average value of a thickness of fan blade 21 between inner edge portion 27 and outer edge portion 26.

More specifically, in the case where thicknesses of fan blade 21 at positions where recess 41A, recess 41B, and recess 41C are formed are defined as T1, T2, and T3, respectively, thicknesses T1, T2, and T3 are equal to or greater than the average value of the thicknesses of fan blade 21 between inner edge portion 27 and outer edge portion 26. The average value of the thicknesses of fan blade 21 is calculated from measurement values obtained, for example, by measuring a thickness of fan blade 21 at each position set by dividing a distance between inner edge portion 27 and outer edge portion 26 into 10 equal parts (except for the position where recess 41 is formed).

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According to such a construction, a thickness of fan blade 21 at each position where recess 41 is formed can be prevented from becoming too small, and strength of fan blade 21 can sufficiently be ensured.

FIG. 16 is a perspective view showing the fan blade in FIG. 2. FIG. 17 is a cross-sectional view showing the fan blade along the line XVII-XVII in FIG. 16. FIG. 18 is a cross-sectional view showing the fan blade along the line XVIII-XVIII in FIG. 16. FIG. 17 shows a cross-section on a one end 31 side of fan blade 21, while FIG. 18 shows a cross-section on the other end 32 side of fan blade 21.

Referring to FIGS. 16 to 18, fan blade 21 is formed with resin molding by using molding die 160 shown in FIG. 8. Here, in consideration of a draft of movable die 162, fan blade 21 is formed to have such a tapered shape as being inclined with respect to the axial direction of central axis 101. More specifically, fan blade 21 is formed such that a cross-sectional area obtained in the case where it is cut in a plane orthogonal to central axis 101 increases from one end 31 toward the other end 32 (S3<S4).

In fan blade 21 having such a construction, recess 41 is formed such that its cross-sectional area is greater on the other end 32 side than on the one end 31 side (S5<S6). Recess 41 is formed such that a cross-sectional shape continuously changes in the axial direction of central axis 101. Recess 41 is formed such that its groove depth is greater on the other end 32 side than on the one end 31 side (H1<H2). Recess 41 is formed such that a width of opening in its blade surface 23 is greater on the other end 32 side than on the one end 31 side (B1<B2).

According to such a construction, a shape of recess 41 is changed such that a cross-sectional area of recess 41 is great on the other end 32 side having a greater cross-sectional area. Thus, weight of fan blade 21 can significantly be reduced while strength thereof is ensured.

A structure of cross-flow fan 100 in the first embodiment of this invention described above is summarized. Cross-flow fan 100 serving as a fan in the present embodiment has fan blades 21 as a plurality of vane portions provided at a distance from one another in a circumferential direction. Fan blade 21 has inner edge portion 27 arranged on the inner circumferential side and outer edge portion 26 arranged on the outer circumferential side. Blade surface 23 extending between inner edge portion 27 and outer edge portion 26 and constituted of positive pressure surface 25 and negative pressure surface 24 is formed in fan blade 21. Positive pressure surface 25 is arranged on a side of a direction of rotation of the fan and negative pressure surface 24 is arranged on a back side of positive pressure surface 25. As the fan rotates, an air flow as a fluid flow which flows between inner edge portion 27 and outer edge portion 26 is generated over blade surface 23. Fan blade 21 has such a blade cross-sectional shape that large-thickness portion 40 at which thickness T between positive pressure surface 25 and negative pressure surface 24 is greatest is arranged closer to inner edge portion 27 which is any one of inner edge portion 27 and outer edge portion 26, when it is cut in a plane orthogonal to central axis 101 serving as a rotation axis of the fan. Recess 41 recessed in blade surface 23 is formed at a position closer to inner edge portion 27 as any one of inner edge portion 27 where large-thickness portion 40 is arranged and outer edge portion 26, than to outer edge portion 26 as any the other of inner edge portion 27 and outer edge portion 26.

According to cross-flow fan 100 in the first embodiment of this invention thus constructed, since fan blade 21 has such an aerofoil cross-section that fan blade 21 has large-thickness portion 40 arranged closer to inner edge portion 27, good

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static pressure characteristics can be obtained. Meanwhile, by forming recess 41 at a position closer to inner edge portion 27 where large-thickness portion 40 is formed, weight of fan blade 21 can be reduced while strength thereof is ensured. Here, as vortex 105, 107 of an air flow is generated in recess 41, air flow 106, 108 over blade surface 23 can be stabilized. Therefore, weight of fan blade 21 can be reduced while an effect of improvement in static pressure characteristics is maintained. Consequently, cross-flow fan 100 having light weight and exhibiting excellent air flow capability can be realized.

Moreover, according to air conditioner 210 in the first embodiment of this invention, by employing cross-flow fan 100 having light weight and exhibiting excellent air flow capability, power consumption in the drive motor for driving cross-flow fan 100 can be reduced. Thus, air conditioner 210 capable of contributing to energy saving can be realized.

Second Embodiment

A variety of variations of cross-flow fan 100 in the first embodiment and fan blade 21 included in cross-flow fan 100 will be described in the present embodiment.

FIG. 19 is a perspective view showing a first variation of the cross-flow fan in FIG. 1. FIG. 20 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 19.

Referring to FIGS. 19 and 20, in the present variation, in fan blade 21, in addition to recess 41, a recess 43 as an additional recess is formed. Recess 43 is formed as being recessed in blade surface 23. Recess 43 is formed at a position closer to outer edge portion 26 than to inner edge portion 27 where large-thickness portion 40 is arranged, that is, in outer circumferential side region 52. Recess 43 is formed in negative pressure surface 24.

Recess 43 is in a shape of a groove extending along the axial direction of central axis 101. Recess 43 is formed to extend continuously between one end 31 and the other end 32 of fan blade 21 in the axial direction of central axis 101. Recess 43 is formed to extend linearly between one end 31 and the other end 32 of fan blade 21 in the axial direction of central axis 101.

Recess 43 has a triangular cross-section when cut in a plane orthogonal to central axis 101. Recess 43 is not limited to such a shape, and for example, it may have a trapezoidal or arc-shaped cross-section. Though a single recess 43 is formed in negative pressure surface 24 in outer circumferential side region 52 in the present variation, a plurality of recesses 43 may be formed.

Recess 43 is formed to be smaller in groove depth than recess 41 (H6<H3, H4, H5).

FIG. 21 is a cross-sectional view showing a downstream-side region in the case where the cross-flow fan in FIG. 19 is applied to an air conditioner.

Referring to FIG. 21, in the figure, downstream-side region 242 in FIG. 6 is shown, and an air flow from inner space 247 to downstream-side outer space 248 is formed. Here, centrifugal force toward a radially outward direction with central axis 101 being defined as the center is applied to air which passes between adjacent fan blades 21 as shown with an arrow 131. In this case, since positive pressure surface 25 is arranged to face the inner circumferential side, air to which centrifugal force is applied flows as if it strongly impinged on the outer circumferential side of positive pressure surface 25. Thus, in the case where a recess is provided in positive pressure surface 25 in outer circumferential side region 52, there is a concern that dust is accumulated in that recess.

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On the other hand, since negative pressure surface 24 is arranged to face the outer circumferential side on a rear surface of positive pressure surface 25, air does not strongly impinge on negative pressure surface 24. Therefore, an effect of weight reduction of fan blade 21 owing to provision of recess 43 can be obtained without concerns about deposition of dust in recess 43.

In addition, in the present variation, recess 43 is formed to be smaller in groove depth than recess 41. According to such a construction, a thickness of fan blade 21 can be prevented from becoming extremely small in outer circumferential side region 52 smaller in thickness than inner circumferential side region 51. Moreover, in resin molding a cross-flow fan with the use of molding die 160 in FIG. 8, fluidity of the resin in outer circumferential side region 52 small in thickness can be ensured.

FIG. 22 is a perspective view showing a second variation of the cross-flow fan in FIG. 1. FIG. 23 is a cross-sectional view showing a fan blade included in the cross-flow fan in FIG. 22.

Referring to FIGS. 22 and 23, in the present variation, large-thickness portion 40 is arranged closer to outer edge portion 26, of inner edge portion 27 and outer edge portion 26. Large-thickness portion 40 is arranged in outer circumferential side region 52 closer to outer edge portion 26 than to inner edge portion 27. Large-thickness portion 40 is arranged adjacent to outer edge portion 26. Large-thickness portion 40 is arranged at a position where a length of blade surface 23 between outer edge portion 26 and large-thickness portion 40 is smaller than a length of blade surface 23 between large-thickness portion 40 and the position of boundary between inner circumferential side region 51 and outer circumferential side region 52. Fan blade 21 has such a blade cross-section that a thickness is relatively great on the outer circumferential side and relatively small on the inner circumferential side as a whole.

A recess 46 is formed in fan blade 21. Recess 46 is formed as being recessed in blade surface 23. Recess 46 is formed at a position closer to outer edge portion 26 where large-thickness portion 40 is formed than to inner edge portion 27, that is, in outer circumferential side region 52. No recess is formed at a position closer to inner edge portion 27 than to outer edge portion 26 where large-thickness portion 40 is arranged, that is, in inner circumferential side region 51. Recess 46 is formed in positive pressure surface 25. No recess is formed in negative pressure surface 24. A plurality of recesses 46 are formed in fan blade 21.

In the case where the cross-flow fan in the present variation is applied to an air conditioner, when an air flow from upstream-side outer space 246 toward inner space 247 is formed in upstream-side region 241 in FIG. 7, an effect of pressure recovery owing to an enlarging flow path can be obtained in air flow path 55 between adjacent fan blades 21.

FIG. 24 is a cross-sectional view showing a first variation of the fan blade shown in FIG. 23. Referring to FIG. 24, in the present variation, in fan blade 21, in addition to recess 46, a recess 47 is formed. Recess 47 is formed at a position closer to outer edge portion 26 where large-thickness portion 40 is arranged, than to inner edge portion 27, that is, in outer circumferential side region 52. Recess 47 is formed in negative pressure surface 24. Recess 46 and recess 47 are formed at positions opposed to each other with centerline 28 lying therebetween. A plurality of recesses 47 are formed in fan blade 21.

According to such a construction, an effect of reduction in weight of fan blade 21 can more effectively be obtained by recess 47 formed in negative pressure surface 24.

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FIG. 25 is a cross-sectional view showing a second variation of the fan blade shown in FIG. 23. Referring to FIG. 25, fan blade 21 in the present variation is different from fan blade 21 shown in FIG. 24 in position where recess 47 is formed. In the present variation, recess 46 and recess 47 are formed at positions displaced from each other with centerline 28 lying therebetween. Recess 46 and recess 47 are arranged to be staggered along centerline 28.

According to such a construction, a thickness of fan blade 21 can be prevented from becoming extremely small at positions where recess 46 and recess 47 are formed, and an effect of sufficiently ensuring strength of fan blade 21 can further be achieved.

FIG. 26 is a cross-sectional view showing a third variation of the fan blade shown in FIG. 23. Referring to FIG. 26, fan blade 21 in the present variation is different from fan blade 21 shown in FIG. 25 in the number of recesses 47 formed. In the present variation, a single recess 47 is formed in fan blade 21.

According to such a construction, as compared with fan blade 21 shown in FIG. 25, such a phenomenon that an air flow over negative pressure surface 24 separates in the downstream of recess 47 can more reliably be avoided.

FIG. 27 is a cross-sectional view showing a fourth variation of the fan blade shown in FIG. 23. Referring to FIG. 27, in the present variation, as compared with fan blade 21 shown in FIG. 25, recess 46 is not formed but only recess 47 recessed in negative pressure surface 24 is formed.

FIG. 28 is a cross-sectional view showing a fifth variation of the fan blade shown in FIG. 23. Referring to FIG. 28, fan blade 21 in the present variation is different from fan blade 21 shown in FIG. 23 in the number of recesses 46 formed. In the present variation, a single recess 46 is formed in fan blade 21. Recess 46 is arranged at a position where a length of blade surface 23 between recess 46 and the position of boundary between inner circumferential side region 51 and outer circumferential side region 52 is smaller than a length of blade surface 23 between outer edge portion 26 and recess 46.

In the present variation, no recess is provided at a position close to outer edge portion 26 originally having a large-thickness shape but recess 46 is provided at a position where a thickness is small, which is distant from outer edge portion 26. Thus, an effect of improvement in static pressure characteristics owing to a large-thickness blade is achieved by fan blade 21 itself at a position close to outer edge portion 26 and by a vortex flow formed in recess 46 at a position where recess 46 is formed.

It is noted that the variations shown in FIGS. 24 to 28 are also applicable to fan blade 21 in which large-thickness portion 40 is arranged closer to inner edge portion 27.

FIG. 29 is a cross-sectional view showing a third variation of the cross-flow fan in FIG. 1. Referring to FIG. 29, in the cross-flow fan in the present variation, the plurality of fan blades 21 are constituted of a plurality of types of fan blades 21A, 21B, 21C, 21D, 21E, 21F. In fan blades 21A to 21F, recesses 41 are formed in forms different from one another. There are provided a plurality of fan blades 21A to a plurality of fan blades 21F.

A form of providing recess 41 means a shape of recess 41 (a cross-sectional shape, a groove depth, a width of opening, and the like), a position where recess 41 is formed, and the number of recesses 41. In the present variation, three recesses 41 are formed in each of fan blades 21A, 21C, two recesses 41 are formed in each of fan blades 21B, 21D, and a single recess 41 is formed in each of fan blades 21E, 21F. In fan blades 21B, 21C, 21E, recess 41 relatively great in groove depth is formed, and in fan blades 21A, 21D, 21F, recess 41 relatively small in groove depth is formed.

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Fan blades **21A**, **21B**, **21C**, **21D**, **21E**, **21F** are aligned in an irregular (random) order in the circumferential direction around central axis **101**. Namely, fan blades **21A** to **21F** are aligned such that they are not repeatedly aligned in a regular order (for example, such an order as fan blade **21A**→**21B**→**21C**→**21D**→**21E**→**21F**→**21A**→**21B**→**21C**→**21D**→**21E**→**21F**→**21A**→**21B** . . .).

In the cross-flow fan shown in the figure, in a prescribed section, in a clockwise direction around central axis **101**, fan blades **21A**, **21B**, **21C**, **21D**, **21E**, **21F**, **21C**, **21B**, **21F**, **21A**, **21D**, **21E**, **21B**, **21F**, **21E**, **21C**, **21A**, **21D** are sequentially aligned.

In the example above, a method of sequentially arranging a plurality of sets different in sequence of fan blades **21A** to **21F** with six types of fan blades **21A** to **21F** being defined as one set is adopted as a method of randomly arranging fan blades **21A** to **21F**. Other than this method, a method of preparing a plurality of fan blades **21A** to a plurality of fan blades **21F** and selecting an appropriate fan blade among them and aligning them sequentially may be employed. If fan blades **21A** to **21F** are aligned without regularity as a whole, a specific type of fan blades may successively be aligned. Recesses **41** different in form from one another may be provided in all of fan blades **21** employed in the cross-flow fan. The number of types of fan blades **21** used is preferably three or more and more preferably four or more.

According to such a construction, as the form of recess **41** differs, a shape, a size, or the number of vortexes of an air flow formed in recess **41** is different in fan blades **21A** to **21F**. In this case, since an air flow along the outside of that vortex is also affected by the shape, the size, or the number of vortexes, a direction or a velocity of an air flow in the downstream of recess **41** can vary among fan blades **21A** to **21F**. Thus, frequencies of passing sounds of fan blades **21** can be distributed and noise in connection with drive of the fan can be suppressed.

According to the cross-flow fan in the second embodiment of this invention thus constructed, an effect described in the first embodiment can similarly be obtained.

Third Embodiment

In the present embodiment, a structure of a centrifugal fan to which the fan according to the present invention is applied will initially be described, and then a structure of a blower and an air cleaner including that centrifugal fan will be described. It is noted that the centrifugal fan in the present embodiment includes a structure partially similar to that of cross-flow fan **100** in the first embodiment. Description of a redundant structure will not be repeated below.

(Description of Structure of Centrifugal Fan)

FIG. **30** is a perspective view showing a centrifugal fan in a third embodiment of this invention. Referring to FIG. **20**, centrifugal fan **10** in the present embodiment has a plurality of fan blades **21**. Centrifugal fan **10** has appearance in a substantially cylindrical shape as a whole, and the plurality of fan blades **21** are arranged around a circumferential surface of the substantially cylindrical shape. Centrifugal fan **10** is integrally formed from resin. Centrifugal fan **10** rotates in a direction shown with arrow **103** around virtual central axis **101** shown in FIG. **30**.

Centrifugal fan **10** is a fan for sending air taken from the inner circumferential side toward the outer circumferential side by using the plurality of rotating fan blades **21**. Centrifugal fan **10** is a fan sending air in a radial direction from a central side of rotation of the fan by making use of centrifugal force. Centrifugal fan **10** is a sirocco fan. Centrifugal fan **10** is

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used at the number of revolutions in a range of low Reynolds numbers applied to fans in home electric appliances or the like.

Centrifugal fan **10** further has an outer circumferential frame **13p** and an outer circumferential frame **13q** each serving as a support portion. Outer circumferential frame **13p** and outer circumferential frame **13q** are formed to annularly extend around central axis **101**. Outer circumferential frame **13p** and outer circumferential frame **13q** are arranged at positions distant from each other in the axial direction of central axis **101**. In outer circumferential frame **13p**, a boss portion **16** for coupling centrifugal fan **10** to the drive motor with a disk portion **14** being interposed is integrally formed.

The plurality of fan blades **21** are aligned at a distance from one another in the circumferential direction around central axis **101**. The plurality of fan blades **21** are supported by outer circumferential frame **13p** and outer circumferential frame **13q** at opposing ends in the axial direction of central axis **101**. Fan blade **21** is formed to be erected on outer circumferential frame **13p** and to extend along the axial direction of central axis **101** toward outer circumferential frame **13q**.

Fan blade **21** has a blade cross-sectional shape the same as that of fan blade **21** in FIG. **4** in the first embodiment. Namely, large-thickness portion **40** at which a thickness of fan blade **21** is greatest is arranged closer to inner edge portion **27**, of inner edge portion **27** and outer edge portion **26**. Recess **41** is formed at a position of fan blade **21**, closer to inner edge portion **27** where large-thickness portion **40** is arranged, than to outer edge portion **26**.

Centrifugal fan **10** in the present embodiment is different from cross-flow fan **100** in the first embodiment in that the plurality of fan blades **21** are aligned at regular intervals.

(Description of Structure of Blower and Air Cleaner)

FIG. **31** is a cross-sectional view showing a blower in which the centrifugal fan in FIG. **30** is employed. FIG. **32** is a cross-sectional view showing the blower along the line XXXII-XXXII in FIG. **31**. Referring to FIGS. **31** and **32**, a blower **320** has a drive motor **328**, centrifugal fan **10**, and a casing **329** in an outer casing **326**.

An output shaft of drive motor **328** is coupled to boss portion **16** molded integrally with centrifugal fan **10**. Casing **329** has a guide wall **329a**. Guide wall **329a** is formed substantially from a $\frac{3}{4}$ arc arranged around the outer circumference of centrifugal fan **10**. Guide wall **329a** increases a velocity of an air current while guiding an air current generated as a result of rotation of fan blade **21** in a direction of rotation of fan blade **21**.

An intake portion **330** and an outlet portion **327** are formed in casing **329**. Intake portion **330** is formed as being located on an extension of central axis **101**. Outlet portion **327** is formed to open in a part of guide wall **329a** into one tangential direction of guide wall **329a**. Outlet portion **327** forms a prismatic shape protruding from a part of guide wall **329a** to one tangential direction of guide wall **329a**.

As drive motor **328** is driven, centrifugal fan **10** rotates in the direction shown with arrow **103**. Here, air is taken from intake portion **330** into casing **329** and sent from an inner circumferential side space **331** to an outer circumferential side space **332** of centrifugal fan **10**. Air sent to outer circumferential side space **332** flows in the circumferential direction along a direction shown with an arrow **304** and sent to the outside through outlet portion **327**.

FIG. **33** is a cross-sectional view showing an air cleaner in which the centrifugal fan in FIG. **30** is employed. Referring to FIG. **33**, an air cleaner **340** has a housing **344**, a blower **350**, a duct **345**, and an (HEPA: High Efficiency Particulate Air Filter) filter **341**.

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Housing **344** has a rear wall **344a** and a top wall **344b**. Housing **344** has an intake port **342** formed, for taking in air in a room in which air cleaner **340** is installed. Intake port **342** is formed in rear wall **344a**. Housing **344** further has an outlet port **343** formed, for discharging cleaned air into the room. Outlet port **343** is formed in top wall **344b**. Air cleaner **340** is generally installed against a wall such that rear wall **344a** is opposed to a wall in the room.

Filter **341** is arranged to face intake port **342** in the inside of housing **344**. The air introduced into housing **344** through intake port **342** passes through filter **341**. Thus, foreign matters in air are removed.

Blower **350** is provided for taking air in the room to the inside of housing **344** and sending the air cleaned by filter **341** into the room through outlet port **343**. Blower **350** has centrifugal fan **10**, a casing **352**, and a drive motor **351**. Casing **352** has a guide wall **352a**. Casing **352** has an intake portion **353** and an outlet portion **354**.

Duct **345** is provided above blower **350** and is provided as an air channel for guiding the cleaned air from casing **352** to outlet port **343**. Duct **345** has a prismatic shape with its lower end connecting to outlet portion **354** and with its upper end open. Duct **345** is formed to guide the cleaned air blown from outlet portion **354** to a laminar flow toward outlet port **343**.

In air cleaner **340** having such a construction, as blower **350** is driven, fan blade **21** rotates to cause air in the room to be taken in from intake port **342** to the inside of housing **344**. Here, an air flow is generated between intake port **342** and outlet port **343**, and foreign matters such as dust included in the intake air are removed by filter **341**.

The cleaned air obtained by passage through filter **341** is taken into the inside of casing **352**. Here, the cleaned air taken into the inside of casing **352** forms a laminar flow through guide wall **352a** around fan blade **21**. The air in the form of a laminar flow is guided to outlet portion **354** along guide wall **352a** and blown from outlet portion **354** to the inside of duct **345**. The air is discharged from outlet port **343** toward an outer space.

Though the air cleaner has been described in the present embodiment by way of example, other than this, for example, the centrifugal fan according to the present invention can be applied to such an apparatus for sending a fluid as an air conditioner, a humidifier, a cooling apparatus, and a ventilating apparatus.

According to centrifugal fan **10** and air cleaner **340** in the third embodiment of this invention thus constructed, an effect described in the first embodiment can similarly be obtained.

A new fan may be constructed by combining as appropriate structures of the fans described in the first to third embodiments described above. For example, the various fan blades described in the second embodiment may be employed to construct centrifugal fan **10** in the third embodiment.

It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

INDUSTRIAL APPLICABILITY

This invention is mainly applied to home electric appliances having an air blowing function, such as an air cleaner and an air conditioner.

REFERENCE SIGNS LIST

10 centrifugal fan; **12**, **12A**, **12B**, **12C** impeller; **13**, **13p**, **13q** outer circumferential frame; **13a**, **13b** end surface; **14**

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disk portion; **16** boss portion; **21**, **21A** to **21F** fan blade; **23** blade surface; **24** negative pressure surface; **25** positive pressure surface; **26** outer edge portion; **27** inner edge portion; **28** centerline; **31** one end; **32** the other end; **40** large-thickness portion; **41**, **41A** to **41C**, **42**, **43**, **46**, **47** recess; **51** inner circumferential side region; **52** outer circumferential side region; **55** air flow path; **100** cross-flow fan; **101** central axis; **105**, **107**, **111** vortex; **160** molding die; **162** movable die; **164** stationary die; **166** cavity; **210** air conditioner; **215** blower; **220** indoor unit; **222** casing; **222A** cabinet; **222B** front panel; **224** intake port; **225** outlet port; **226** air-blow passage; **228** air filter; **229** indoor heat exchanger; **231** lateral louver; **232** vertical louver; **242** upstream-side region; **242** downstream-side region; **246** upstream-side outer space; **247** inner space; **248** downstream-side outer space; **251** front wall portion; **252** rear wall portion; **253**, **254** projection; **256** upper guide portion; **257** lower guide portion; **262** forced vortex; **320** blower; **326** outer casing; **327** outlet portion; **328** drive motor; **329** casing; **329a** guide wall; **330** intake portion; **331** inner circumferential side space; **332** outer circumferential side space; **340** air cleaner; **341** filter; **342** intake port; **343** outlet port; **344** housing; **344a** rear wall; **344b** top wall; **345** duct; **350** blower; **351** drive motor; **352** casing; **352a** guide wall; **353** intake portion; and **354** outlet portion.

The invention claimed is:

1. A fan, comprising:

a plurality of vane portions including an inner edge portion arranged on an inner circumferential side and an outer edge portion arranged on an outer circumferential side and provided at a distance from one another in a circumferential direction,

said vane portion including a blade surface, which extends between said inner edge portion and said outer edge portion and is constituted of a positive pressure surface arranged on a side of a direction of rotation of the fan and a negative pressure surface arranged on a back side of said positive pressure surface,

a fluid flow which flows between said inner edge portion and said outer edge portion being generated over said blade surface as the fan rotates,

said vane portion including such a blade cross-sectional shape that a large-thickness portion at which a thickness between said positive pressure surface and said negative pressure surface is greatest is arranged closer to either of said inner edge portion and said outer edge portion when it is cut in a plane orthogonal to a rotation axis of the fan, when cut in the plane orthogonal to the rotation axis of the fan, said vane portion has a cross-sectional area increasing from one end toward the other end,

a recess recessed in said blade surface being formed at a position closer to either of said inner edge portion and said outer edge portion where said large-thickness portion is arranged, than to any the other of said inner edge portion and said outer edge portion, wherein

of said positive pressure surface and said negative pressure surface, it is only said positive pressure surface in which said recess is formed,

said recess is formed to extend from the one end to the other end of said vane portion in the direction of the rotation axis of the fan, and

said recess is formed such that a cross-sectional area of said recess recessed in said blade surface is greater on a side of the other end than on a side of the one end.

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2. The fan according to claim 1, wherein said recess is formed such that said vane portion at a position where said recess is formed has a thickness equal to or greater than an average value of a thickness of said vane portion between said inner edge portion and said outer edge portion. 5
3. The fan according to claim 1, wherein a plurality of said recesses are formed as being aligned in a direction of connection of said inner edge portion and said outer edge portion to each other. 10
4. The fan according to claim 1, wherein the plurality of said vane portions include a first vane portion and a second vane portion different in the form of said recess formed in said vane portion.
5. The fan according to claim 1, wherein said vane portion has a thickness increasing from either of said inner edge portion and said outer edge portion toward said large-thickness portion and decreasing from said large-thickness portion toward any the other of said inner edge portion and said outer edge portion. 15
6. The fan according to claim 1, wherein said large-thickness portion is arranged closer to said inner edge portion than to said outer edge portion, said recess is formed as being recessed in said positive pressure surface at a position closer to said inner edge portion than to said outer edge portion, 20
an additional recess is further formed in said vane portion, and
said additional recess is formed as being recessed in said negative pressure surface at a position closer to said outer edge portion than to said inner edge portion.

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7. The fan according to claim 6, wherein said additional recess recessed in said negative pressure surface is smaller in depth than said recess recessed in said positive pressure surface.
8. The fan according to claim 1, wherein on an inside of the plurality of said vane portions aligned in the circumferential direction, an inner space is formed, and on an outside thereof, an outer space is formed, and the fan is a cross-flow fan for taking a fluid from said outer space on one side with respect to the rotation axis into said inner space when viewed in the direction of the rotation axis of the fan and sending the taken fluid to said outer space on the other side with respect to the rotation axis.
9. The fan according to claim 1, wherein on an inside of the plurality of said vane portions aligned in the circumferential direction, an inner space is formed, and on an outside thereof, an outer space is formed, the fan is a centrifugal fan for sending a fluid from said inner space to said outer space, and said large-thickness portion is arranged closer to said inner edge portion than to said outer edge portion.
10. The fan according to claim 1, formed from resin.
11. A molding die for use in molding the fan according to claim 10.
12. A fluid feeder, comprising a blower constituting a fan according to claim 1 and a drive motor coupled to said fan to rotate the plurality of said vane portions.

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